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New biostratigraphic and palaeoecologic observations on the «Plattenkalk» of the Lower Cretaceous (Albian) of Pietraroia (Benevento, S Italy), and its decapod crustaceans assemblage

Abstract – A biostratigraphic and sedimentologic analysis of the stratigraphical sequence outcropping at the NE side of Civita di Pietraroia has been carried out. Such sequence includes two plattenkalk horizons with fossil vertebrates, as well as the facies facing their layer. The abundance of microfossils in the above-mentioned facies allows to update plattenkalks to Lower Albian. The sedimentological facies of these plattenkalks outlines some sedimentary environments, characterised by very shallow lagoons, located quite close to a coastal area, and mainly filled by event sedimentation of muddy materials, more or less mixed to organogenic particulate (small tests of foraminifers, fragments of molluscs, sponge spicules) swept from basin-surrounding carbonatic platform areas. Such sedimentary events, linked to tide rhythms and storms, alternated to more or less prolonged sedimentary starvation intervals, when dystrophic conditions established in the lagoons. The presence of bioturbations, the preservation state of vertebrates, the taphonomy of bivalve molluscs and the sometimes abundant presence of land plants, as well as continental organisms, respectively prove the incomplete anoxia of sea-beds, the overheating of lagoonal water, probably often close to the limit of emertion and the presence of overlooking lands above the sea level.

Together with the biostratigraphic and palaeoecologic study, a small sample of macruran and anomuran decapod crustaceans is accurately analysed. Most of the sample was found during palaeontological excavations carried out in 1982 by the Palaeontology Department of the Università di Napoli, in collaboration with the Museo di Storia Naturale di Torino. A smaller part of the sample was collected during a test excavation carried out in October 1996 by the Palaeontology Department of the Università di Napoli in collaboration with the Invertebrate Palaeontology Department of the Museo di Storia Naturale di Milano. The study of this sample led to the description of the genus *Micropenaeus* nov. with the species *M. tenuirostris* n.sp. (infraorder Penaeidea de Haan, 1849, family Penaeidae Rafinesque, 1815). The genus *Parvocaris* nov. with the species *P. samnitica* n.sp. belongs to the infraorder Caridea Dana, 1852, family indeterminate. The new genus *Huxleycaris* with the species *Huxleycaris beneventana* n.sp. (infraorder Anomura Milne-Edwards, 1832, family Axiidae Huxley, 1879) is also described. It is the first report on this family in the Italian Cretaceous. So far the Italian literature on decapod crustaceans was based on many Triassic faunistic associations (Cene, Seriana Valley - Bergamo; Ponte Giurino, Imagna Valley - Bergamo; Prati di Rest, Valvestino - Brescia; Val Preone, Carnia - Udine), Jurassic associations (Osteno, Lugano Lake - Como), and Cretacic associations (Vernasso and Torrente Cornappo Valley, Udine; Trebiciano, Trieste), found during the last decade in the Alps. Therefore the discovery of the decapod crustaceans of Pietraroia, together with those of Petina (Monti Alburni, Salerno - S Italy; see the work in-

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cluded in this paper), plays a very important role, since it is the only report on Cretacic decapod crustaceans found outside the Alps.

Riassunto – Nuove osservazioni biostratigrafiche e paleoecologiche sul «plattenkalk» del Cretacico inferiore (Albiano) di Pietraroia (Benevento, S. Italia), e la sua fauna a crostacei decapodi.

Viene fornita un'analisi biostratigrafica e sedimentologica della successione stratigrafica affiorante al versante NE della Civita di Pietraroia, comprendente due orizzonti di plattenkalk con vertebrati fossili, nonchè le facies interposte al tetto al letto di essi. L'abbondanza di microfossili presenti nelle suddette facies permette di precisare all'Albiano inferiore l'età dei plattenkalks. La facies sedimentologica di questi ultimi delinea degli ambienti sedimentari identificabili con lagune piuttosto prossime ad un'area costiera, con profondità molto limitata e sedimentazione prevalentemente legata ad apporti episodici di materiali fangosi, più o meno misti a fine particolato organogeno (piccoli gusci di foraminiferi, frammenti di molluschi, spicole di spugne) spazzati dalle aree di piattaforma circostanti i bacini. Tali eventi sedimentari legati a ritmi mareali e tempeste, erano alternati a pause più o meno prolungate nella sedimentanione, durante le quali si instauravano condizioni distrofiche nelle acque delle lagune. La presenza di bioturbazioni, lo stato di fossilizzazione dei vertebrati, la tafonomia dei molluschi bivalvi e la presenza, talora abbondante, di resti di piante terrestri, oltre che di organismi continentali, documentano rispettivamente la non completa anossia dei fondali, il surriscaldamento delle acque lagunari, probabilmente al limite con l'emersione e la presenza di prospicienti aree emerse.

Oltre lo studio biostratigrafico e paleoecologico, viene analizzato in dettaglio un piccolo campione di crostacei decapodi macruri e anomuri, rinvenuto in gran parte nel corso dello scavo paleontologico del 1982, effettuato dal Dipartimento di Paleontologia dell'Università di Napoli in collaborazione con il Museo di Storia Naturale di Torino e in piccola parte a seguito di un saggio di scavo effettuato nel mese di ottobre 1996 dal Dipartimento di Paleontologia dell'Università di Napoli in collaborazione con la Sezione di Paleontologia degli Invertebrati del Museo di Storia Naturale di Milano. Lo studio di questo campione ha portato alla descrizione del genere *Micropenaeus* nov. con la specie *M. tenuirostris* n.sp. (infraordine Penaeidea de Haan, 1849, famiglia Penaeidae Rafinesque, 1815). Il genere *Parvocaris* nov. con la specie *P. samnitica* n.sp. appartiene all'infraordine Caridea Dana, 1852, famiglia indeterminata. Viene inoltre descritto il nuovo genere *Huxleycaris* con la specie *Huxleycaris beneventana* n.sp. (infraordine Anomura Milne-Edwards, 1832, famiglia Axiidae Huxley, 1879). Si tratta della prima segnalazione di questa famiglia nel Cretacico italiano. Finora le conoscenze italiane relative ai crostacei decapodi si basavano su numerose associazioni faunistiche triassiche (Cene, Val Seriana - Bergamo; Ponte Giurino, Val Imagna - Bergamo; Prati di Rest, Valvestino - Brescia; Val Preone, Carnia - Udine), giurassiche (Osteno, Lago di Lugano - Como) e cretaciche (Vernasso e Valle del Torrente Cornappo, Udine; Trebiciano, Trieste), rinvenute nell'arco alpino in questi ultimi dieci anni. Il rinvenimento quindi dei crostacei decapodi di Pietraroia, insieme a quelli di Petina (Monti Alburni, Salerno - S. Italia; vedi lavoro nel presente volume), riveste una particolare importanza in quanto si tratta delle uniche segnalazioni di crostacei decapodi cretacici al di fuori dell'arco alpino.

Introduction

The plattenkalk of Pietraroia (province of Benevento), is well known in the literature starting from the first quarter of last century, and its vertebrate fauna is mentioned also in reviews and papers by recent authors (Patterson, 1970, Bartram, 1977, Bravi, 1988, 1994, Leonardi & Teruzzi, 1993, Barbera & Macuglia, 1988).

The age of the plattenkalk has been the subject of controversial opinions, even though it has generally been considered coeval with that of Capo d'Orlando, near Castellamare di Stabia (Naples), and they both have

been ascribed mainly to Jurassic (Covelli, 1839, Agassiz, 1833-43, Pilla, 1833), to Neocomian, to Lower Cenomanian (Bassani, 1882-85, De Lorenzo, 1896, Bassani & D'Erasmo, 1912, D'Erasmo, 1915) and, starting from the sixties, to Aptian (D'Argenio, 1963, Cerchi, De Castro & Schroeder, 1978). Recent biostratigraphical studies on the Pietraroia sequence (Bravi & De Castro, in press) prove that it formed in Lower Albian. This result, quite important for the region's geology, will allow to more precisely speculate on the evolution of Cretaceous fishes.

The plattenkalk reflects particular environmental conditions within the carbonatic platform, characterised by proximity to lands above the sea level, poor exchange with the open sea, poor oxygenation, sedimentation cyclicity, very limited depth, conditions often close to the limit of emersion.

Geological setting of the studied area

The Civita di Pietraroia (I.G.M. sheet 162 III SW - Cusano Mutri) (Fig. 1) on which the homonymous small town is built, is a monocline structure variously dissected by faults, with an average dip of the strata of about 15° E-SE. It is located on the eastern border of the Matese massif and is well
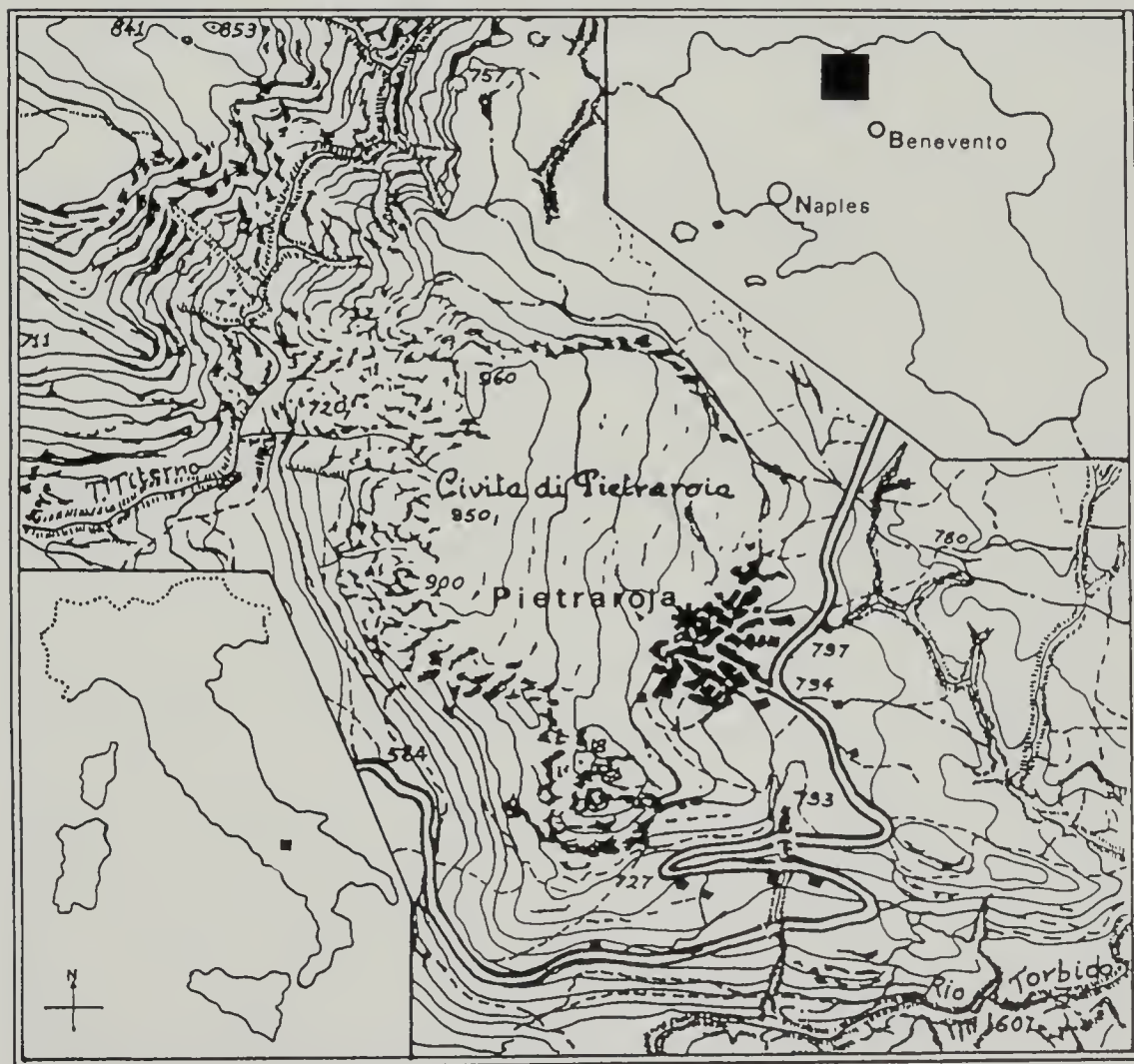

Fig. 1 – Location of the studied area (I.G.M. sheet 1:25.000: 162 III SW - Cusano Mutri).

delimited by faults with a NW-SE e NE-SW trend and surrounded by deep valleys, on the bottom of which the Titerno stream (Fosso Acqua Calda) and Rio Torbido flow. The eastern slope of the Civita degrades very steeply for about 400 m., from the ridge at a height of 960 m. a.s.l. to the bed of the Titerno stream, while the western wall gently degrades east, with a slope of about 10%. The body of the structure is crossed by faults, some of which are inverse, with poor E-W and ESE-WNW eastern scarp and with N vergency.

On the basis of the works by D'Argenio (1963), Catenacci & Manfredini (1963) and Freels (1975), the outcropping stratigraphical sequence consists of about 300-320 m. of limestones and dolomitic limestones, sometimes dolomites, Lower Cretaceous in age; it is possible to observe two different parts (D'Argenio, 1963):

Lower part

About 250 m of fossiliferous intramicrites, sometimes turning into biomicrites with a Havana-brown and grey colour in layers and banks, with green clay-marly interbeds getting more frequent in the upper part. There are also calcareous-dolomitic and dolomitic horizons. In the lowest part of this stretch it is possible to find traces of small rustidaceans (*Requienia* ?) and turreted gastropods that can be ascribed to *Nerinea*. In the upper part it is possible to find traces of lamellibranchia and recrystallized gastropods of difficult interpretation.

This section of the series partly corresponds to the «G assemblage (gastropods and Requienie limestones)» of the series of western Matese by Catenacci, De Castro & Sgrosso (1963); it has been described as «compact limestones of Pietraroia» or «primitive sedimentary rock» by Costa (1865), and as «white limestones in large layers» by Galdieri (1913) and «lower light-coloured limestones» by D'Erasmo (1915). This lower section of the series recognised by D'Argenio, corresponds to the «lower assemblage» by Catenacci & Manfredini (1963).

Upper part

The upper part of the sequence recognised by D'Argenio consists of 50-70 m of fossiliferous micrites and intramicrites and intrasparrudits; the lower levels, recognisable even from a distance, consist of thin layers with mollusc «lumachellas», often fragmentary and difficult to ascribe. They are gradually followed by whitish, havana and light hazel-coloured, detrital, sometimes oolitic and pseudoolitic limestones in layers and banks, with calcareous-conglomeratic horizons with a calcareous cement. It is possible to observe marks of recrystallized gastropods, turreted gastropods and ostreid shells. The ichthyolytic limestones of Pietraroia represent a heteropic horizon within this section of the sequence.

This upper part of the sequence of the Civita corresponds to the «intermediate assemblage» and «upper assemblage» by Catenacci & Manfredini (1963) (Fig. 2). These authors found *Cuneolina camposauri* (Sartoni & Crescenti), *C. laurentii* (Sartoni & Crescenti) and *Salpingoporella dinarica* Radoicic in the mid-lower section of their «upper assemblage». They also reported the presence of a horizon containing *Orbitolina* spp and *Charophytes gyrogonites* in the limestones with *Salpingoporella dinarica*. Moreover, according to Catenacci & Manfredini (1963), the last layers of the upper assemblage, where the Mesozoic series ends up, contain a microfauna similar

to that found in the detritic limestone horizons of ichthyolitic limestones, with primitive Cuneolines, Miliolids, Textularids, *Glomospira* and ostracods. On the basis of such micropalaeontological observations and of similarities with comparable thanatocenoses studied in Southern Apennines, (De Castro, 1962, Sartoni & Crescenti, 1962, Catenacci, De Castro & Sgrosso, 1963), the authors ascribe the whole series to Lower Cretaceous, except for the basal part, which can be ascribed to Malm. More precisely the section consisting of ichthyolitic limestones could be dated back to a period between Barremian and Albian.

Miocene overlaps Mesozoic in unconfomity and not marked by bauxite horizons, with light-coloured limestones, partly of a biostromal origin, which also fill the borings by lithophagous molluscs involving the highest part of the outcropping Mesozoic sequence (especially the «ichthyolitic limestones»). Such light-coloured limestones contain ostreids, pettinids, rhodoliths, briozoans and fish teeth, as well as benthonic foraminifers, among which *Heterostegina* sp., *Amphistegina* sp., *Miogypsina* sp., and they are followed by «Orbulina silty marls» of the Longano Formation, which deposition is linked to the deepening of the Abruzzi-Campania platform during the Langhian-Seravallian transgression. The latter part of the sequence is dated back to Elvetian-Langhian. The sequence is closed by flyschioid terrigenous sediments of turbiditic type (Pietraroia Formation) outcropping in the most southern section of the Civita.

Previous knowledge on the sedimentation environment
The first environmental remarks on the deposit were made by Galdieri (1913): the presence of fine-grained limestones and cherts led him to believe that they represented a quite deep deposit. It was only at the beginning of the sixties, thanks to the exhaustive work by D'Argenio (1963), that new remarks were made: according to this author, the fish deposit originated from a slowing down of the subsidence rate of the platform, thus creating a very shallow lagoonal environment, with negligible kinetic energy and occasional communications with the open sea, occasionally with emersion conditions. This would be confirmed by mud cracks both in the limestones and in the chert beds, as well as by the accumulation of such cracked chips - which can sometimes be found in the plattenkalk sequence - and by gaspits. In these conditions the death of fishes would be caused by the reducing environment created by limited exchanges with the open sea and the death of large masses of phytoplankton in a relatively calm weather. On the contrary Catenacci & Manfredini (1963) believe that the deposit took place in a transition strip between the margin of the platform and the deepest sediments of the opposite basin (Molise-Sannitica depression). This environment, heteropic with platform neritic limestones, was probably characterised by recurrent bathymetric variations which caused the irregular alternation of «semicontinental» and lagoonal conditions with open-sea conditions. The authors so explain the presence of very different organisms and litotypes (amphibians, reptilians and crustacea from the one side, fish and chert on the other side, together with radiolarians and sponge spicules. But such alternation of «semicontinental» conditions is in contrast with the «open sea» condition in an «external marginal position» as opposed to the

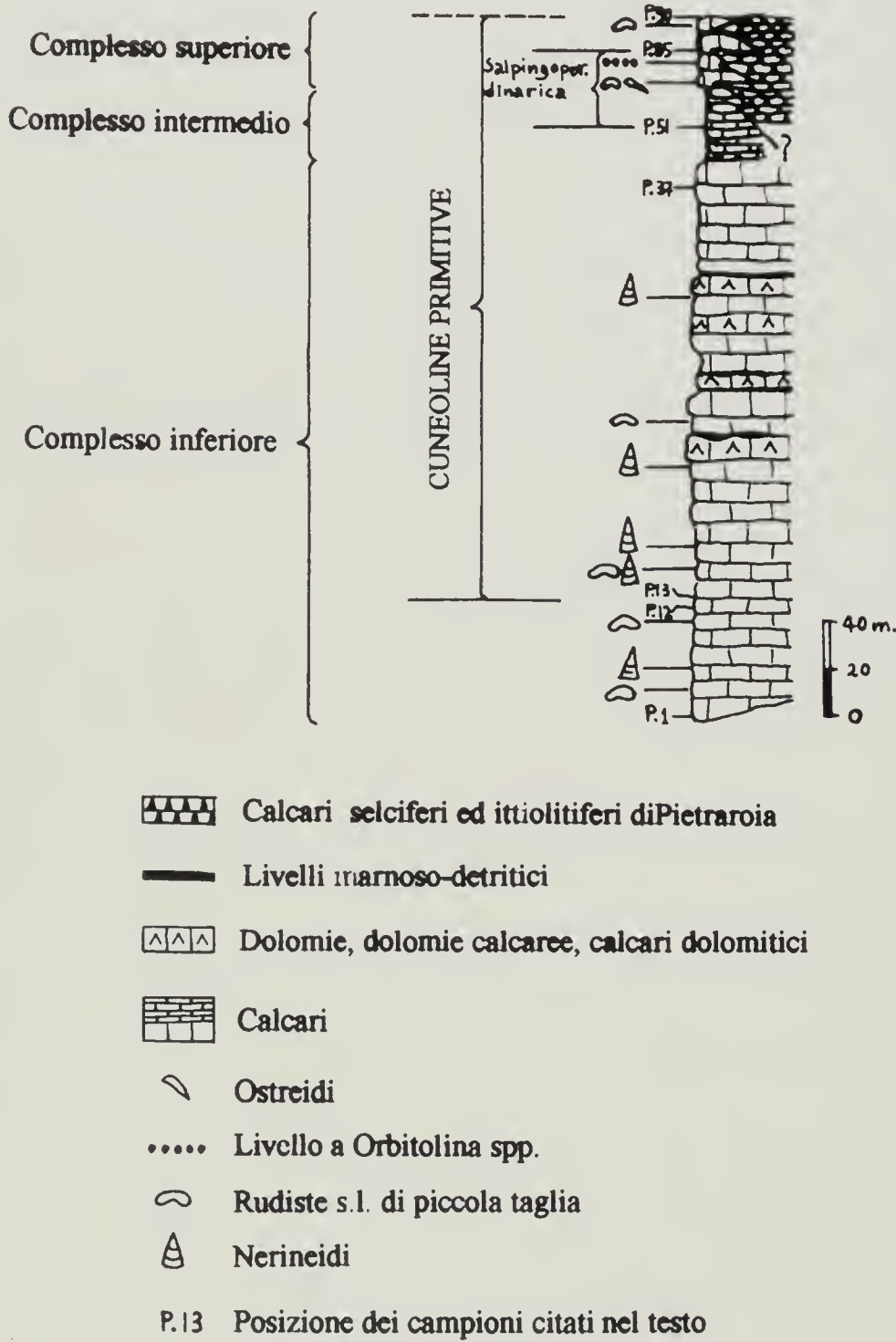# PROFILO SCHEMATICO DELLA SERIE DI PIETRAROIA

(F. 162 - III SO)

Complesso superiore

Complesso intermedio

Complesso inferiore

CUNEOLINE PRIMITIVE

Salpingopor. dinarica

P.32
P.25
P.51
P.37
P.13
P.12
P.1

40 m.
20
0

Calcari selciferi ed ittiolitiferi di Pietraroia

Livelli marnoso-detritici

Dolomie, dolomie calcaree, calcari dolomitici

Calcari

Ostreidi

Livello a Orbitolina spp.

Rudiste s.l. di piccola taglia

Nerineidi

P.13   Posizione dei campioni citati nel testo

Fig. 2 – Stratigraphy of the Civita di Pietraroia. From Catenacci & Manfredini (1963).

platform. Fairly recently Freels (1975) stated that the Pietraroia ichthyolitic deposit formed in a underwater erosion basin with low environmental energy and reducing conditions toward the sea-bottom (stagnant deposits by Seilacher, 1970), not deeper than 60 m, heteropic of less deep limestones in carbonatic platform facies. The filling up of such basin should be due to small suspension currents (turbidites) carrying detrital materials from the borders of the basin itself. The author justifies his interpretation by the presence of slumpings that can be observed at the borders of the ichthyolitic basin and by the gradation of certain layers of the plattenkalk. Consistently with his hypothesis, the structures that D'Argenio thought were due to chert drying up are ascribed to contraction phenomena (subacqueous shrinkage).

Previous knowledge on the location of outcrops and plattenkalk stratigraphy

On the basis of the remarks made by different authors during the last century, the first significant observations on the arrangement and stratigraphy of the outcrops of Pietraroia plattenkalk were made by D'Erasmo (1915), who supplied the following stratigraphical sequences:

a) Outcrop located at «Le Cavere», from bottom to top:

1) light-coloured, fine-grained limestones with conchoidal fracture, without macrofossils (Cenomanian)

2) greyish, tough, compact and very fine-grained limestones, with conchoidal fracture, sometimes containing ichthyolites, with chert bands and nodules (Cenomanian)

3) white, often breach-shaped and compact Tertiary limestones with Pettinids, unlike the previous one

b) Outcrop located at «Ortupapa», from bottom to top:

1) light-coloured, fine-grained limestones without fossils
2) greyish limestones, identical to the ichthyolitic limestones
3) light-coloured limestones with Nerineids
4) light-grey oolitic limestones
5) almost white limestones, with Requienids

In site b (Ortupapa) Pecten Tertiary limestones are often lacking, unlike the underlying structures. Sometimes they can be found in certain lithodomus borings in the ichthyolitic limestones. This supplied Galdieri (1913) the material for a study, which will not only illustrate the stratigraphy and tectonics of the Civita di Pietraroia, but will also try to determine the species of lithofagous mollusc that made the borings. More recently an analysis of the area arrangement of the fish horizons and their relationships with the neighbouring rocks has been carried out by Catenacci & Manfredini (1963). These authors recognised the presence of one single ichthyolitic horizon at least 50 m thick and supplied with interfingering ending in a flute-beak termination with the neighbouring, non-ichthyolitic isochronous rocks. The illustration supplied by the authors (Catenacci & Manfredini, 1963, fig. 9, page 74) shows such interfingerings on the northern wall of the Civita, while the outcropped horizon, getting thicker in the body of the monocline struc-

ture, cannot be completely observed. According to the authors, the ichthyolitic limestones, well exposed on the eastern wall of Vallenova, are composed of: compact lutitic limestones, often with a conchoidal fracture, with a light havana, whitish and ash-grey colour, thinly stratified, sometimes marly and laminated limestones, easy breaking in thin slabs, sometimes with microgranular, detritic calcareous intervals and with dolomicritic interstrata, foul when hit. These limestones are intercalated by small layers of blackish, grey, brown chert, sometimes concentrated in lenses and nodules. Certain horizons of these limestones are rich in different organic remains (remains of fishes, crustaceans, molluscs, coprolites and plants). In the detritic intervals of the ichthyolitic limestones Catenacci & Manfredini (1963) found primitive Cuneolines, Miliolids, Textularids, *Glomospira* and Ostracods, while in the mudstones they found Radiolars, sponge spicules and forms that could probably be ascribed to *Praeglobotruncana*. D'Argenio (1963), while mentioning the sites of ichthyolitic limestones outcroppings at the Civita di Pietraroia (Vallenova, Le Cavere, northern and western wall of the Civita), stresses that the above-mentioned flute-beak terminations are not so evident and he ascribes some of them to tectonic phenomena. He also links the ichthyolitic limestones of Pietraroia to stratigraphically and lithologically analogous outcrops, located at Monte Cigno and at the Cusano Civita. According to this author, the thickness of the ichthyolitic limestones of Pietraroia is not greater than 25-30 m.

Freels (1975) studied the relationships of the plattenkalk with the neighbouring facies, thus supplying a scheme of the planimetric arrangement of the «Le Cavere» deposit (Plattenkalk 4). He fully acknowledges the heteropy of the ichthyolitic limestones ending with a flute-beak termination with the neighbouring formation of «detritic limestones». Freels distinguishes four horizons of ichthyolitic limestones in the assemblage, bottom to top (Plattenkalks 1-4), partly generated by deep interfingerings with the neighbouring facies. Horizons 1 and 2 would outcrop on the steep N and NW walls of the Civita; horizon 4 would outcrop in a wide area of the structural side forming the plateau of the monocline structure and, in section, in the NE wall of the Civita di Pietraroia.

Location of sampled sections of the sequence

Ichthyolitic limestones not only outcrop in the typical «Le Cavere» site (D'Erasmo, 1915, D'Argenio, 1963), but also in the north-eastern wall of the Civita (Fig. 3). A path leads to this site, but the fish layers, outcropping in the wall, are very difficult to reach. Here the following sequence can be observed by proceeding from bottom (path level) to top (summit of the wall), along a thickness of about 50 m:

A) - About 10 m of large limestone banks, delimited at the top by a morphological discontinuity (erosive surface) forming a narrow ledge.

B) - About 6 m of havana-coloured, thinly stratified limestones (Plattenkalk I), getting thinner northward and ending with a «flute-beak» termination against the Cretacic detritic limestones.

C) - About 20 m of limestones apparently arranged in banks of large layers: this aspect is given by the water straining on the rock wall. Limestones are actually arranged in quite thin detritic layers.
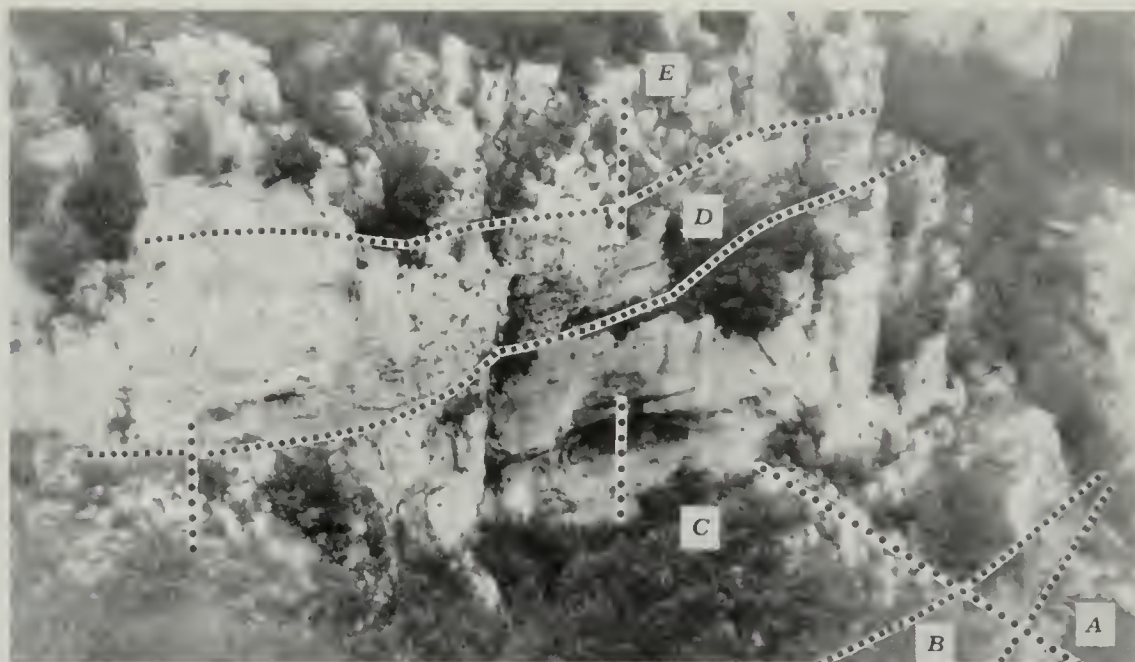
Fig. 3 – NE side of the Civita di Pietraroia. The different intervals of the sampled stratigraphical sequence are marked by broken lines. Intervals B and D correspond to Plattenkalks I and II respectively. The vertical dotted line indicates the sampling path.

D) - 8-10 m of thinly stratified havana-coloured limestones with ichthyolites (Plattenkalk II). This is the same horizon wholly outcropping at the «Le Cavere» site.

E) - 6-7 m of limestone layers and banks belonging to the Cusano formation. These limestones also constitute the brink of the wall by the vertical line of the sequence herewith described.

The above-mentioned stratigraphical sequence of the NE wall of the Civita di Pietraroia seems to be most suited to a sampling aimed at dating the two plattenkalk horizons exposed on the wall, by including Cretaciceous limestone layers both intercalated and arranged on the bed of the plattenkalk horizons. This sequence has been sampled as much as possible, due to the steepness of the wall, along the wall itself, starting from the base of «interval A» up to the first layers of «interval D» (Plattenkalk II) and the last layers, which can be reached from the edge of the wall. The remaining mid-high section of Plattenkalk II, which cannot be reached from the wall, has been sampled at the «Le Cavere» site (Fig. 4), where it constitutes the typical Pietraroia ichthyolitic limestone outcrop. «Interval E» (Cusano Formation), dated back to Miocene, is not described, since it lies outside the aims of this work.

Description of the stratigraphical sequence: biostratigraphy and deposition environment

Interval A (underlying substrate of Plattenkalk I)

This interval, constituting the formation on which the stratigraphically lowest plattenkalk horizon lies, outcrops from the level of the path along the base of the NE wall of the Civita. The thickness of the interval is slightly

Fig. 4 – Outcrop of Plattenkalk II at the typical «Le Cavere» site. The broken line indicates most of the sampled sequence in this site, from the basic layer of the quarry to the surface of the Miocenic transgression.

lower than 10 m, reaching an erosion surface, probably of a subaerial origin, above which the first layers of Plattenkalk I lie (Fig. 3).

The rocks outcropping along the fault plane constituting the wall are made of massive limestone banks, lacking any evident stratification. The sequence lacks any significant tectonic disturbance. The rocks consist mainly of whitish, roughly detritic, often pelletal packstones. Macrofossils that can be observed on the ground are scarce, mostly consisting of small turreted gastropods. Studied by thin section the components of the rock look generally markedly micritised and infested by boring organisms (Fig. 5). It is possible to observe several intraclasts, granule aggregates, lamellibranchia fragments - some of which can be ascribed to requienids - small gastropods, ostracods, hexacoral fragments, very abundant *Bacinella irregularis* Radoicic (Fig. 6), *Giraliarella? prismatica* Arnaud-Vanneau, *Aeolisaccus* sp., several benthonic foraminifers and sometimes algae. The latter consist mainly of nodular cyanophyceans of a *Cayeuxia* type, small rudimentary Thaumatoporelle and scarce *Coptocampylodon* sp.

Several foraminifers are present, among which the most significant from a dating point of view are: Orbitolinids (among which *Paracoskinolina tunesiana* Peybernes and *Cribellopsis cf. arnaudae* Chiocchini, especially abundant in the uppermost section of this stretch, by the erosive surface); *Sabaudia minuta* (Hofker) and *Ovalveolina reicheli* De Castro, together with *Cuneolina laurentii* (Sartoni & Crescenti), evolved Cuneolines (*C. cf. pavonia* D'Orbigny), *Pseudotextulariella scarsellai* (De Castro) and *Praechrysalidina infracretacea* (Luperto Sinni). Rocks located right over the crosive surface consist of detritic packstones, containing the same sedimentological and microfaunistic elements of the substrate, but more scattered in the micritic matrix, also rich in small oncoids. These horizons are sometimes
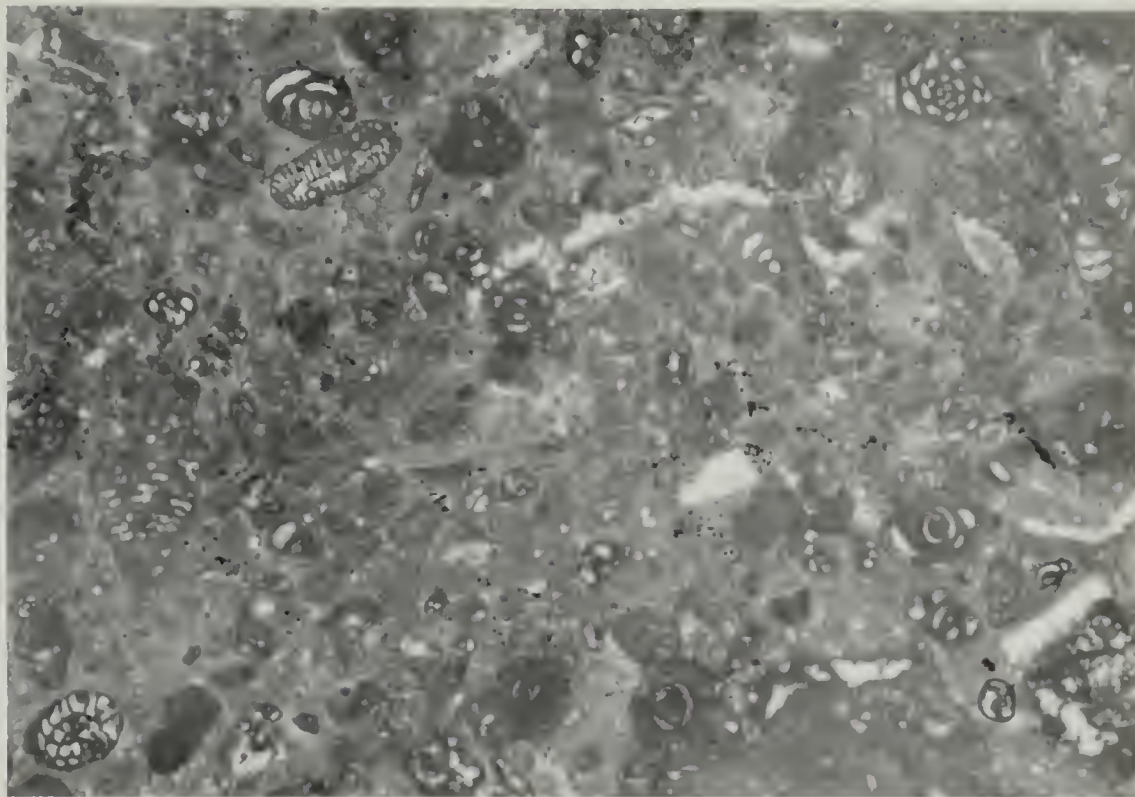
Fig. 5 – Markedly micritised packstone, with intraclasts often covered by oncolitic envelopes, fragments of molluscs and foraminifers, such as *Paracoskinolina tunesiana* Peybernes, *Cribellopsis cfr. arnaudae* Chiocchini, *Ovalveolina reicheli* De Castro, *Praechrysalidina infracretacea* Luperto Sinni, Cuneolina spp. and *Sabaudia minuta* (Hofker), miliolids and textulariids.
Thin section: A.8374d, (x13.5). Locality: NE side of the Civita di Pietraroia (BN). "Interval A": layers immediately underlying Plattenkalk I. Age: early Albian.

graded and turn into wackestone-mudstones, very similar to those typically constituting the layers of the plattenkalk, containing several tiny sparry prismatic fragments, due to the mechanical disintegration of thin bivalve shells. They must be considered as the earliest facies, preluding the true deposition of Plattenkalk I. The above-listed microfossils allow to ascribe this section of the sequence to early Lower Albian (Peybernes et alii, 1981, Cherchi & Schroeder, 1982, Chiocchini, 1989, De Castro, 1991).

The sedimentation environment can be identified in a shallow neritic area within the platform, with a mainly organogenic, detritic and quite coarse sedimentation, with a good circulation of water and rearrangement of the sediment (packstones with abundant intraclasts), which turned out to be infested by *Bacinella irregularis* and cyanobacteria forming micritic envelopes on the granules, likewise the substrate supporting the Cerin Plattenkalk (France), also characterised by an erosive surface (Bernier et alii, 1994). The erosion surface proves that the sea level decreased (probably for eustatic reasons), with emersion and partial erosion of a substrate which was probably already hardened by an early diagenesis due to the above-mentioned organisms. The first layers laying just above the erosive surface prove the setting up of an environment with a more limited circulation (wackestones with fine bivalve debris). The grading of certain horizons and the presence of small oncoids consisting of substrate material reprocessed by cya-
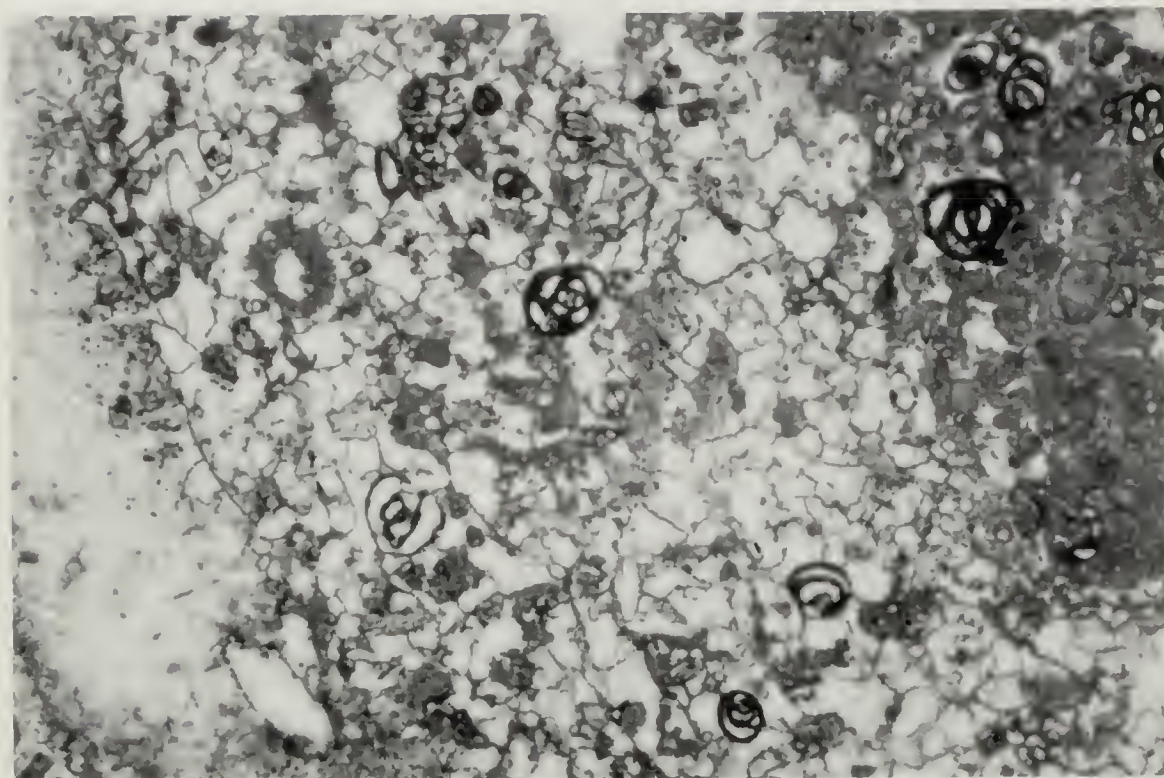
Fig. 6 – Pellet and foraminifer packstone, with fragments of bivalves and shells of gastropods strongly infested by endolitic organisms and *Bacinella irregularis* Radoicic. Foraminifers, even though not all of them are visible in the picture, are constituted by miliolids (such as *Quinqueloculina*, «*Pseudonummoloculina*» and *Spiroloculina*), textulariids, lituolids (such as *Debarina hahounerensis* Fourcade, Raoult & Vila), *Sabaudia minuta* (Hofker), orbitolinids (such as *Paracoskinolina tunesiana* Peybernes), *Pseudotextulariella aff. scarsellai* (De Castro), *Cuneolina aff. laurentii* Sartoni & Crescenti, *Praechrysalidina infracretacea* Luperto Sinni.
Thin section: PKII.ob., (x21).
Locality: Civita di Pietraroia (BN). Left side of the «Vallenova»; detritic facies («Onkolit Bank» by Freels, 1975), heteropic of Plattenkalk II. Age: Lower Albian.

nobacteria prove the beginning of sedimentary mechanisms typical of the plattenkalk, such as the sweeping of shallow sea-bottoms by waves, which transported the suspended sediment into shallow basins, accumulating it in small turbidites by decantation. This change in the sedimentary environment shows the persistence, after the erosive phase, of shallow sea-bed conditions, with the creation of more isolated areas, such as the area where the deposition of Plattenkalk I started.

Interval B (Plattenkalk I)
This interval is about 6 m thick along the sampled vertical line. By moving laterally a few tens of meters northward, it tapers rapidly and ends in a «flute-beak» termination in the embanking rocks (Fig. 3), similar to those of the previous stretch of the sequence. On the contrary, by moving southward, the thickness tends to increase, even though it is not possible to ascertain up to which point, since the plattenkalk sinks rapidly below field level. The layers follow a N 40° E direction, with a dip gradient of about 15° SE. There are no particular tectonic complications. The rocks mainly consist of wackestones and packstones, occasionally of havana-coloured grainstones and mudstones, in flat and even layers with an average thickness

between 3 and 10 cm. A 25 cm thick horizon lies about 1.30 m above the base of the plattenkalk. It consists of large calcareous clasts, with a size of a few centimetres, often with an oncolitic envelope, originating from the previous section of the sequence and basically containing the same microfaunas, together with *Orbitolina* (*Mesorbitolina*) sp. and occasionally dasycladaceans such as *Salpingoporella dinarica* Radoicic and *Triploporella marsicana* Praturlon (Fig. 7). The regular layers of the plattenkalk, examined in a continuous sequence along the above-mentioned interval, show the quite even sequence of grading fine-grained packstone horizons and mudstone-wackestone horizons. The lamination, although often irregular or simply sketched, is almost constantly present inside the layers. No macrofossils can be observed on the ground, and since this formation outcrops in an almost vertical section, it is not possible to examine the whole stratum surfaces in order to ascertain the presence of vertebrate remains or other remains. In thin section it is sometimes possible to observe small carbonatic clasts overlooking the basin and coming from the external areas. Pellets are frequent. Microfossils mainly consist of foraminifers, such as Miliolids, *Glomospira urgoniana*, Texturariids and Valvulinids. Also Orbitolinids (among which *Paracoskinolina tunesiana* and *Cribellopsis cf. arnaudae*), *Sabaudia minuta* and *Cuneolina aff. pavonia* are present, even though in a lower number. There are also fragments of lamellibranchia with thin valves, ostracods with thin carapace, sponge spicules - at times they are quite abundant - holothuria spicules, *Aeolisaccus* sp. and small *Thaumatoporella*.

The age of this interval can be mainly inferred by its stratigraphical position as regards the supporting sublayer and by the microfossiliferous layers right above it (see below). The Lower Albian age of the underlying substrate proves that the plattenkalk cannot be older; the clastic horizon existing in the same plattenkalk - consisting of material coming from the substrate and containing *Ovalveolina reicheli* - cannot be used as a precise chronological reference, because the microfossiliferous associations it contains must be considered as rearranged, even though belonging to a much closer stratigraphical interval. It must be noted that *O. reicheli* does not appear in the layers following the clastic horizon, as well as in the microfossiliferous layers just above Plattenkalk I, mainly containing associations of the orbitolinids *Paracoskinolina tunesiana* and *Cribellopsis cf. arnaudae* instead. All the above allows to ascribe Plattenkalk I to lower Albian (*Sabaudia minuta* zone; De Castro, 1991, Barattolo & De Castro, 1991), but at a stratigraphical interval probably slightly above the interval containing *O. reicheli*. This age is consistent with the remaining part of the microfossiliferous association of the interval.

The sedimentation environment of this stretch of the sequence can be identified, as mentioned above, in a shallow basin located inside and protected by the platform. Exchange with the open sea is quite scarce, probably limited to just very wide tide ranges and meteorological events such as storms, which could produce waves that swept the shelf, thus transporting sediments. These waves were already dampened when they reached the deposition basin of the plattenkalk, and they transported only the finest sediment still suspended. The clastic horizon, containing the same microfossiliferous associations of interval A, as well as dasycladaceans *Salpingoporella*
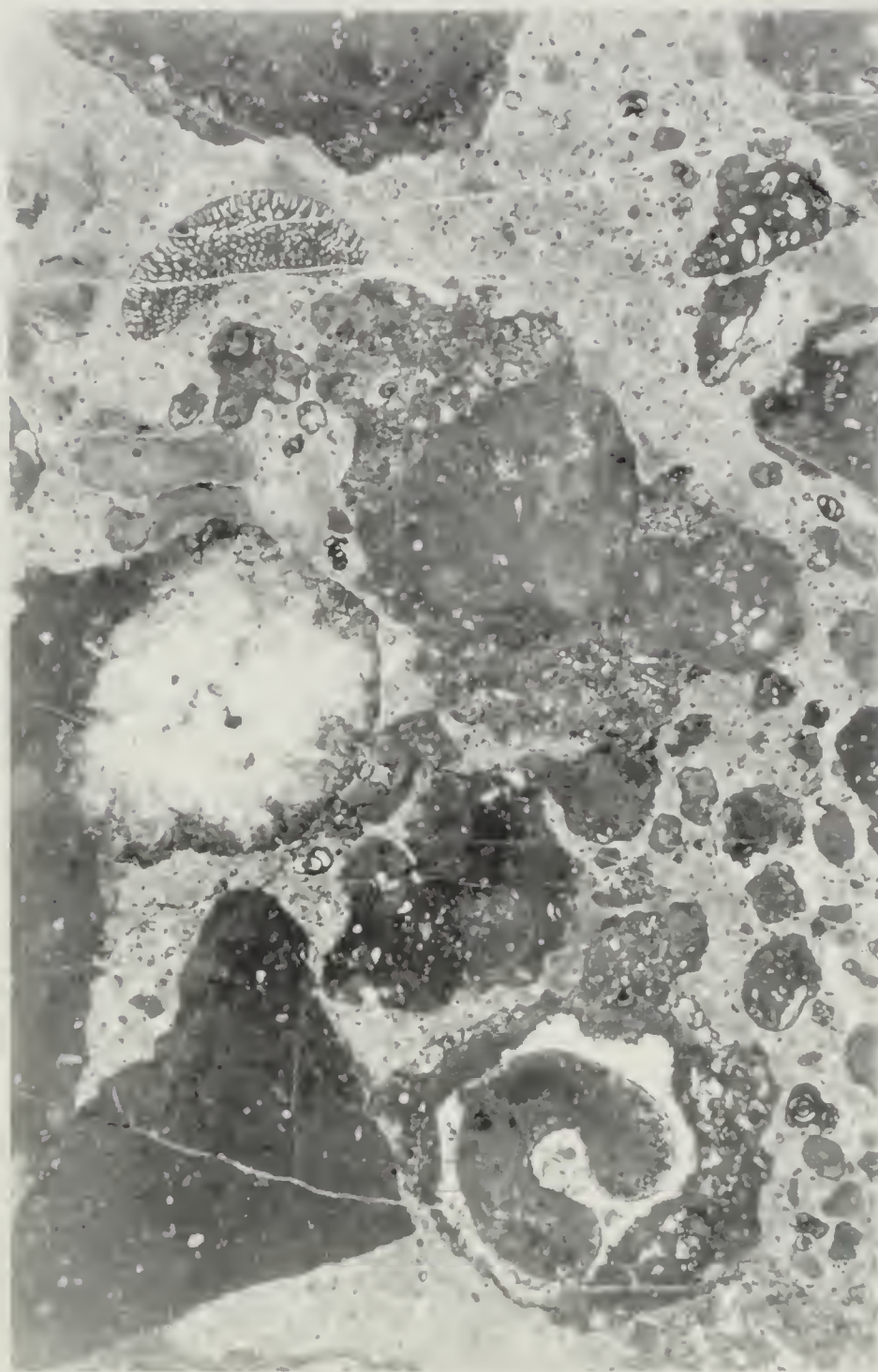
Fig. 7 – Coarsely detritic packstone, with organogenic clasts (fragments of hexacorals, gastropods, bivalves and foraminifers) and micritised limestones, often with sharp corners or oncolitic envelopes. The microfauna, partly inside the clasts, mainly consists of ostracods, textulariids, miliolids (such as *Quinqueloculina*, «*Pseudonummoloculina*», *Sigmoilina* and *Spiroloculina*), «*Valvulammina*», lituolids (such as *Debarina hahounerensis* Fourcade, Raoult & Vila), *Ovalveolina reicheli* De Castro, trochamminids, nubecularids, *Praechrysalidina infracretacea* Luperto Sinni, *Cuneolina laurentii* Sartoni & Crescenti, evolved cuncolines, Orbitolina (*Mesorbitolina*) sp. and *Paracoskinolina tunesiana* Peybernes; *Bacinella irregularis* Radoicic, primitive Thaumatoporellae, *Salpingoporella dinarica* Radoicic, *Triploporella marsicana* Praturlon, *Coptocampylodon* sp. and nodular cyanophiceans of the *Cayeuxia* type are also present. Thin section: A.8375(3.1), (x10.5).
Locality: NE side of the Civita di Pietraroia (BN). «Interval B»: detritic layer, with rearranged material, intercalated in Plattenkalk I. Age: Lower Albian.

dinarica and *Triploporella marsicana*, consisting of rearranged material, represents an occasional sedimentary event with a high kinetic energy, carrying coarse material created by the demolition of slightly older formations existing - maybe in emersion - in the areas neighbouring the sedimentation basin of the plattenkalk.

Interval C (layers interposed between Plattenkalks I and II)

The overall thickness of this section of the sequence is about 18-20 m and the trend of the layers is similar to that of the previous interval. There are no tectonic complications. The well stratified rocks, in layers with an average thickness between 2-3 and 10-15 cm, mainly consist of packstones and often of grainstones and, subordinately, of havana or light-grey coloured wackestones, rich in organogenic debris, sometimes with intraclasts and pellets. The field analysis of this facies shows that it is quite similar to those of the plattenkalks for its thin stratification, for the often fine grain of rocks and for the local presence of laminations. But the stratification surfaces are less regular than those of the plattenkalk layers and there are several stylolithic joints in the body of the layer. No macrofossils can be observed on the ground.

In thin section these rocks are highly microfossiliferous, containing fragments of lamellibranchia, some of which can be ascribed to Requienids and very seldom to Radiolitids, thin fragments of pelagic Pelecipods, sometimes gastropods such as Nerineids and ostracods, fragments of echinoderms, sponge spicules and sometimes holothuriae, scarce isolated hexacorals, uncertain recrystallised forms. Also *Bacinella irregularis*, *Aelisaccus* sp., algae and several foraminifers are present. The latter often show a more or less marked trend to nanism. Among algae *Thaumatoporella* sp is well represented with small and rudimentary forms. Also thalli of nodular cyanophycea such as *Cayeuxia*, *Boueina* sp. are present, although scarce. Foraminifers are mainly represented by Miliolids (among which a high number of *Quinqueloculina*, «*Pseudonummoloculina*», *Glomospira* spp.). They are also represented by Textulariids, Trochamminids, Lituolids, *Cuneolina* spp., *Sabaudia minuta*, *Praechrysalidina infracretacea*, Orbitolinids, among which occasional *Orbitolina* (*Mesorbitolina*) sp. and *Paracoskinolina tunesiana* and *Cribellopsis cf. arnaudae* in great numbers (Fig. 8).

This interval also can be ascribed to Lower Albian (probably to the middle part of the *Sabaudia minuta* zone (De Castro, 1991, Barattolo & De Castro, 1991) for the constant presence of index species and for the high number of associated microfossils.

The deposition environment is undoubtedly more open than that of Plattenkalk I. This is proven by the frequency of coarse-structured detritic packstones and grainstones, as well as by the abundance and variety of the microfauna. But the presence of finely detritic wackestones, at times with sponge spicules and ostracods and thin stratification of this interval, highlight certain conditions characterised by a definitely more limited general circulation than in «interval A», constituting the base of the sequence.

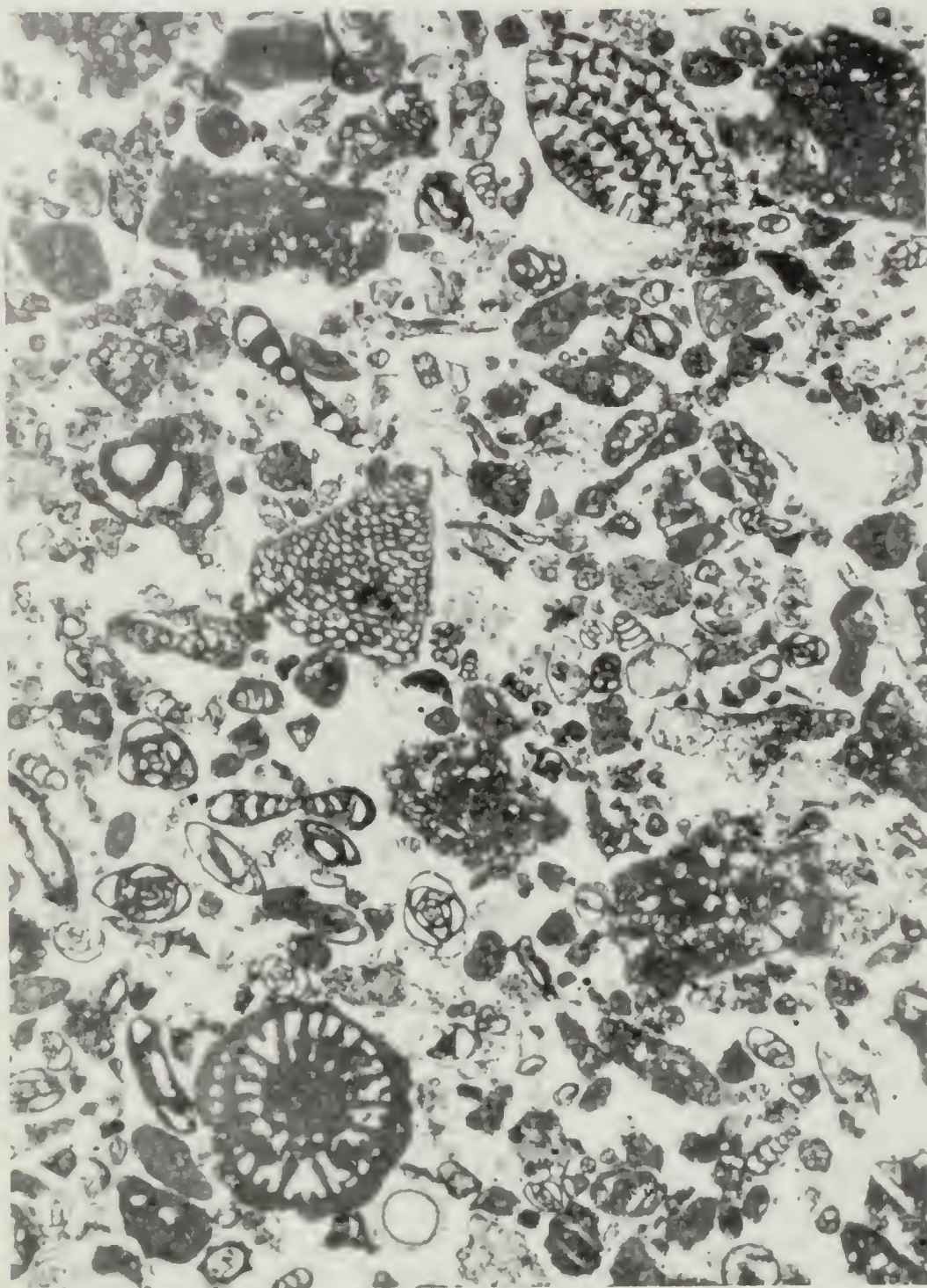Interval D (at the NE wall of the Civita and at «Le Cavere»; Plattenkalk II and the typical «Le Cavere» outcrop)

Fig. 8 – Foraminifer grainstone. The following organisms are present in the association, even though not all of them are visible in the picture: fragments of bivalves and gastropods, miliolids (such as *Quinqueloculina*, «*Pseudonummoloculina*» and *Glomospira*), *Sabaudia minuta* (Hofker), *Cuneolina laurentii* Sartoni & Crescenti, *Pseudotextulariella scarsellai* (De Castro), evolved cuneolines (*C. aff. pavonia* D'Orbigny), *Praechrysalidina infracretacea* Luperto Sinni. lituolids (such as *Debarina hahounerensis* Fourcade, Raoult & Vila), trochamminids, *Paracoskinolina tunesiana* Peybernes, *Cribellopsis cfr. arnaudae* Chiocchini and Fleuryana sp.. There are also *Bacinella irregularis* Radoicic, rare nodular cyanophiceans of the *Cayeuxia* type, *Aeolisaccus* sp., *Giraliarella? prismatica* Arnaud-Vanneau, *Boueina* sp., primitive Thaumatoporellae, fragments of echinoids, hexacorals and polychaeta tubes.

Thin section: A.8384(12.c.7), (x24.5).

Locality: NE side of the Civita di Pietraroia (BN). «Interval C»: layers interposed between Plattenkalk I and Plattenkalk II. Age: late Lower Albian.

This interval corresponds to the typical Pietraroia palaeontological outcrop, wholly outcropping at «Le Cavere» (Fig. 4). It can be observed in section along the NE wall of the Civita (Fig. 3). At this wall it was possible to sample the lowest part of this plattenkalk and its highest layers, including the transgressive transition to the «Cusano» (Selli, 1957) Miocenic formation. The verticalness of the wall makes the intermediate section inaccessible. On the contrary a continuous sampling (layer by layer) has been carried out at «Le Cavere», starting from the lowest layers, outcropping below the road running close to the town, to the top of the plattenkalk, here too generally overcome in paraconformity by transgressive Miocene with Ostreids, Briozoans and Litotamnes. Without assuming a big difference in the plattenkalk thickness between the two outcrops, this stratigraphical interval should correspond to most of the intermediate and upper section of the outcrop exposed on the wall.

Along the sampled section at the NE wall of the Civita, the plattenkalk reaches an overall thickness of 8-9 m, tapering and ending with a «flute-beak» termination a few metres right of the sampling path. On the contrary, while moving right, the thickness tends to increase, probably exceeding 15 m. The trend of the layers is almost identical to that of the previous interval, except by the «flute-beak» termination, where it gets more slanted (at «Le Cavere» the trend of the layers is about N-S leading eastward, with average dip between 20° and 30°). It is not possible to observe particular tectonic complications along the sampled stretch. The rocks are well stratified, in flat and even layers, with an average thickness between 2 and 10 cm. They mainly consist of more or less markedly micritised, havana to hazel or grey-coloured wackestones, mudstones and packstones. These are intercalated by frequent lenses, nodules and beds of grey or blackish cherts (Fig. 9) and marly-calcareous and sometimes clay and thin laminated horizons, particularly at «Le Cavere». The limestone layers are often laminated (Fig. 10) and/or turning from packstones at the base into mudstones at the top.

The thin sections show several microfossils, represented by debris of shells of thin-valved lamellibranchia, in the form of tiny and at times very abundant sparry prisms, smooth and thin-valved ostracods, sponge spicules - sometimes very abundant (Fig. 11) - scarce holothuriae spicules (Fig. 12), *Aeolisaccus* spp., algae - basically consisting of small *Thaumatoporella* and several foraminifers (Fig. 12), which faunas often show a marked trend to nanism. In particular foraminifers are represented by recrystallised porcellanaceous tests, several Miliolids (among which *Quinqueloculina* sp., «*Pseudonummoloculina*» sp. and *Glomospira* spp.), Textulariids, Valvulinids, Trochamminids, Lituolids, *Cuneolina aff. pavonia*, *C. pavonia parva*, *Pseudotextulariella aff. scarsellai*, *Sabaudia minuta* and Orbitolinids (represented by *Paracoskinolina tunesiana* and *Cribellopsis cf. arnaudae*, particularly common in the highest layers of the NE wall of the outcrop, by the transgression surface).

Also the age of Plattenkalk II can be identified with Albian. In particular, the constant presence of *Sabaudia minuta* in the coarsest detritic horizons, in association with evolved Cuneolinae (among which *C. pavonia parva*), several «*Pseudonummoloculina*» and the orbitolinids *Paracoskinolina tunesiana* and *Cribellopsis cf arnaudae*, still numerous also in the highest layers of the plattenkalk, allow to ascribe it to the late part of the lower Al-

Fig. 9 – Plattenkalk II at «Le Cavere» site. Rhythmic horizons of silicified layers (indicated by the arrows). The metric scale corresponds to 40 cm.
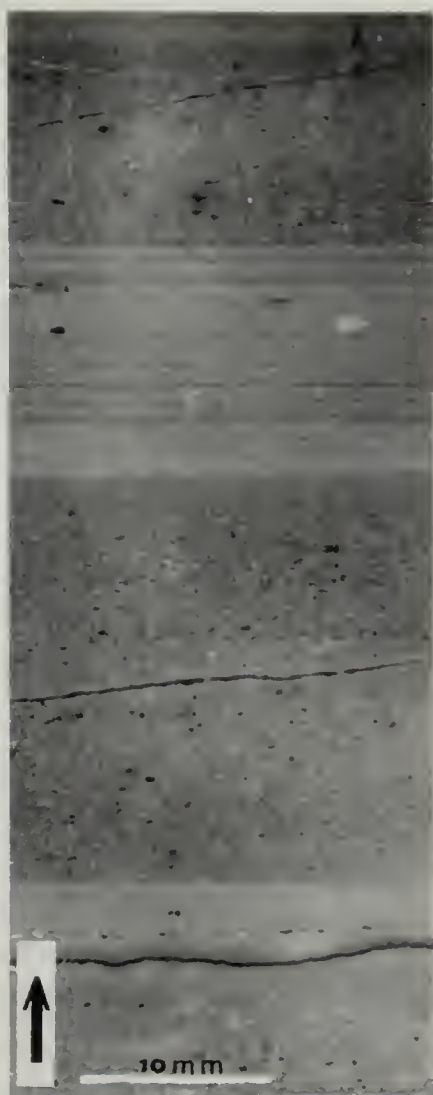
Fig. 10 – Polished sample of a typical limestone layer of Plattenkalk II. It is possible to see three grading coarse-grained horizons (packstone-wackestones), overcome by laminated fine-grained horizons (mudstones). The first two coarse-grained horizons (from the bottom), overcome by mudstone, represent two instantaneous sedimentary events, quite close in time, with final decantation of the finest particulate. The laminated horizon, in the upper half of the picture, represents a longer time interval, with poor sedimentation, before a new instantaneous sedimentary event (coarser horizon at the layer's top). Sample: PKII.31. Scale: in millimetres. Locality: Civita di Pietraroia (BN): «Le Cavere». Upper part of Plattenkalk II. Age: late Lower Albian.

bian, probably corresponding to the last layers of the *Sabaudia minuta* zone (De Castro, 1991, Barattolo & De Castro, 1991).

The sedimentation environment, consisting of a basin with a more limited circulation than the basin where the underlying Plattenkalk I sedimented, will subsequently be discussed into details.

Sedimentological, palaeoecological and taphonomic observations on plattenkalk (I and II) horizons of the civita di pietraparoia

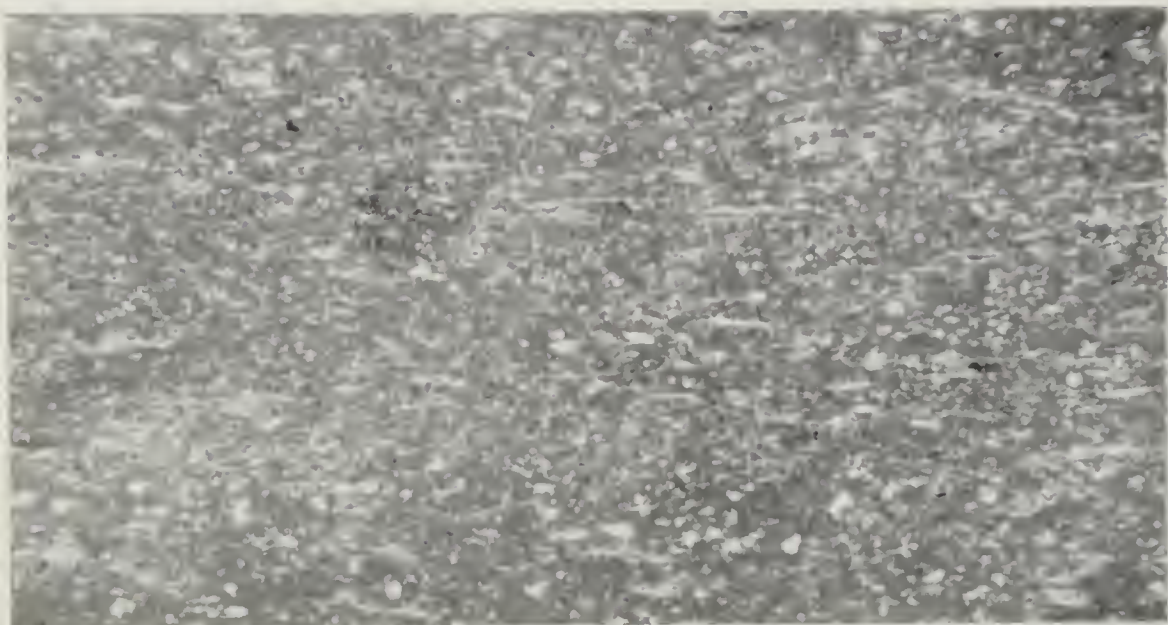Remarks on sedimentary structures and organisation of the layers in the plattenkalks

Fig. 11 – Sponge spicules at Pietraroia plattenkalks. Notice the isoorientation of many spicules. Thin section: PKII.10, (x21.3). Locality: Civita di Pietraroia (BN): «Le Cavere». Plattenkalk II. Age: late Lower Albian.
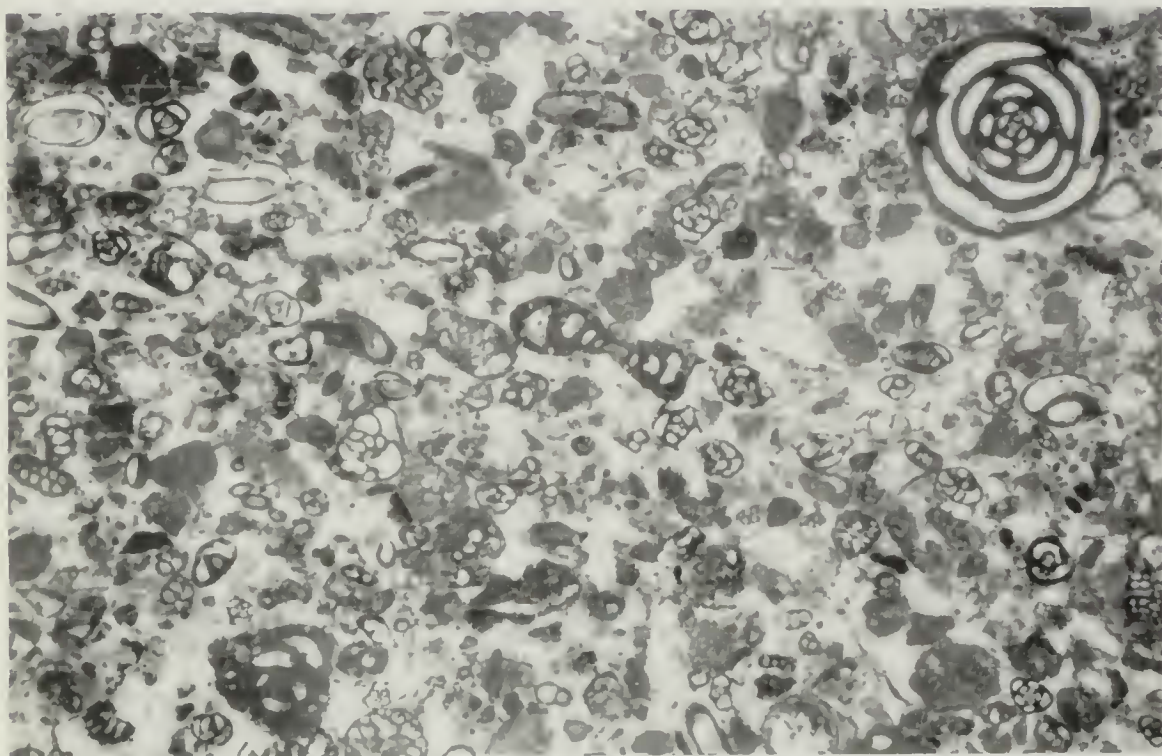

Fig. 12 – Grainstone-packstone detritic horizons with small-sized foraminifers («dwarf fauna»), in the layers of Plattenkalk II. It is possible to see rare regular-sized foraminifers (e.g.: the big «*Pseudonummoloculina*»), occasionally transported together with the finest sedimentary fractions. Miliolids (such as *Quinqueloculina* and «*Pseudonummoloculina*»). *Glomospira* sp., textulariids, trochoid Pfenderina-like tests, *Sabaudia minuta* (Hofker), *Cuneolina laurentii* Sartoni & Crescenti, *C aff. laurentii*, *C. pavonia* D'Orbigny, *C. aff. pavonia*, *Pseudotextulariella aff. scarsellai* (De Castro), *Debarina hahounerensis* Fourcade, Raoult & Vila, *Hemicyclammina*? sp., trochamminids, and small orbitolinids are also present in the association, together with small thaumatoporelle, sponge spicules and rare mud intraclasts.
Thin section: PKII.37, (x21). Locality: Civita di Pietraroia (BN): «Le Cavere». Layers of Plattenkalk II. Age: late Lower Albian.

The following features of the two plattenkalk horizons examined at the Civita di Pietraroia seem to differ:

- Plattenkalk I does not seem to contain silicified horizons, present in Plattenkalk II.
- The layers of Plattenkalk I show more uneven surfaces and less frequent and regular inner laminations than the layers of Plattenkalk II.
- Marly-calcareous thin laminated horizons and clay horizons - frequent in Plattenkalk II - are not present in Plattenkalk I.
- Plattenkalk I is probably less fossiliferous than Plattenkalk II.
- Fine-grained litotypes (Mudstones s.s.) are less present in Plattenkalk I than in Plattenkalk II.

The above-mentioned differences can be partly due to the position of the sample inside the formation, since Plattenkalk I tapers and ends in a «flute-beak» termination not far from the studied stratigraphic log. Also in Plattenkalk II, at the «Vallenova» site, by moving toward its margins, chert intervals decrease, as well as macrofossils, while the granulometric size of the sediment increases (Freels, 1975).

On the basis of the above-mentioned remarks, the described differences could also correspond to an actual difference in the sedimentation environment of the two horizons. Plattenkalk I in particular could have formed in a basin less isolated from the open sea and slightly deeper (constantly subtidal environment) than the deposition basin of Plattenkalk II. The layer of the former shows in fact a less variable thickness and more homogeneous lithologies, since they generally consist of packstones gradually turning into wackestones and mudstones. This would indicate, together with the lack of marly-calcareous thin laminated horizons - which are here interpreted as sedimentary starving periods - less variable environmental factors, with continuous sediment supply of fine materials transported by waves, taken from the lagoonal areas surrounding the basin and poured into it. These materials were deposited by microturbiditic mechanisms.

The continuous sequence of the sample of most layers of Plattenkalk II outcropping at «Le Cavere» stresses an apparent cyclicity in the lithotype distribution. Such cyclicity is represented, especially in the first meter, starting from the basic layer of the quarry, by a quite regular sequence of calcareous layers, thin dark-coloured siliceous layers and marly-calcareous thickly laminated horizons. The upper part of the outcrop, on the contrary, lacks any marly thin laminated horizons, and a rhythmic alternation of calcareous layers and silicified horizons can be observed (Fig. 9). The calcareous layers consist of one or many packstone horizons gradually turning into wackestones-mudstones, often with inner lamination (Figs. 13-14). These graded intervals represent single microturbiditic sedimentary or decantation events, followed by more or less prolonged non-depositionary pauses. The thin siliceous layers often contain remains of abundant microfaunas and foraminifers, sometimes regular-sized, rather than tending to nanism. As far as the silicification causes are concerned, the coarse grain of some of these layers and the following deposition of thin marly-calcareous and clay laminae can be interpreted as the sequence of a sedimentary event supplying sediments with a higher intergranular porosity, and of a more or less prolonged non-depositionary or quite reduced carbonatic deposition stage.

Fig. 13 – Graded horizons, due to instantaneous events (microturbidites), in the layers of Plattenkalk II. The two events are separated by thin blackish interstrata, due to the final decantation of organic particulate or maybe to the development of a thin bacterial or algal film on the sea-bottom, in the time interval between two sedimentary events. Thin section: PK11.23b, (x21). Locality: Civita di Pietraroia (BN): «Le Cavere». Layers of Plattenkalk II. Age: late Lower Albian.

during which the supply of terrigenous materials (clays) taken from overlooking continental areas prevails. These particular ecological conditions could determine the heavy blooming of bacteria, responsible for the precipitation of siliceous gels which concentrated, thanks to their high specific weight, in the intergranular cavities of the immediately underlying coarsest layers. Alternatively silica, already present in solution in the probably low-
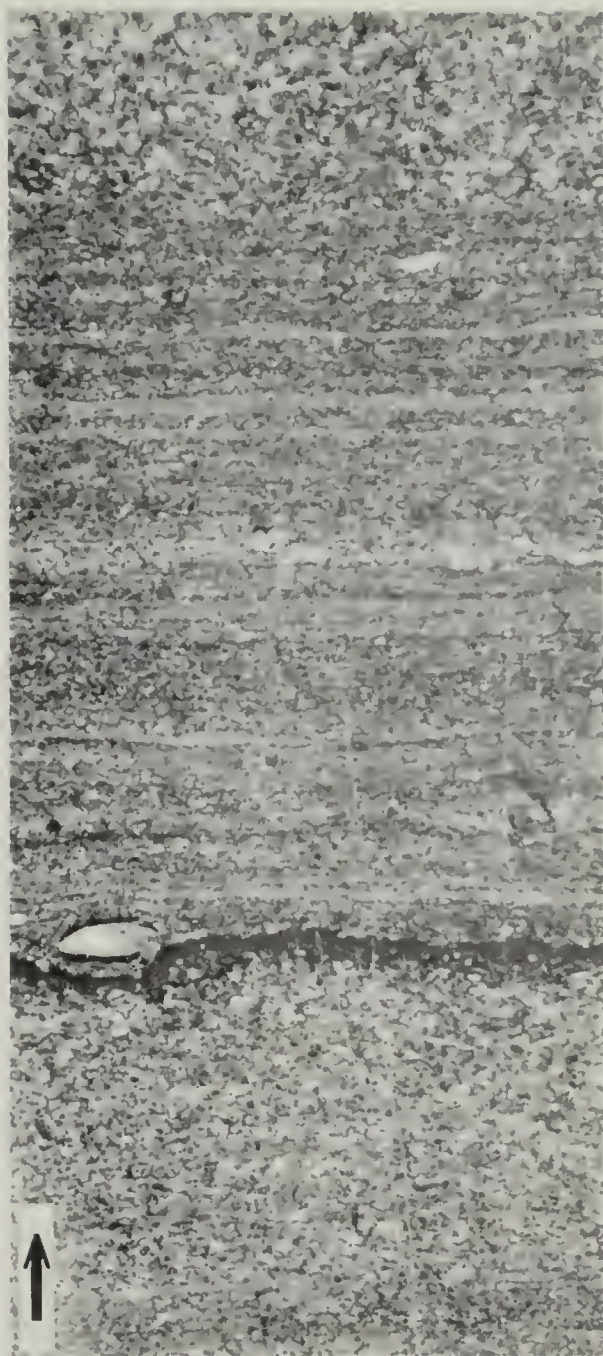
Fig. 14 – Very fine-grained packstone horizons (at the bottom and top of the picture) and thin microdetritic laminations (centre of the picture), in the limestone layers of Pietraroia plattenkalks. Thin section: PKII.3(2). (x10.5). Locality: Civita di Pietraroia (BN): «Le Cavere», Plattenkalk II. Age: late Lower Albian.

salinity basin water, could flocculate because of the supply of «new water» and coarser sediments from the open sea, according to D'Argenio (1963). The silicification of these totally widespread horizons can be considered, in agreement with D'Argenio (1963), as syngenetic or at least penecontemporaneous to the sedimentation (thus confirming the hypothesis of a bacterial origin), also because the siliceous layers are often fractured in cracks, and the upper surface of the underlying calcareous layers show the marks of such cracks, surrounded by protruding borders, with and upside-down V section. This indicates that the silicification already took place when the underlying muddy layer was still plastic, and that subacqueous shrinkage phenomena (Freels, 1975) led to the fracture of the siliceous layers which, be-

cause of a higher specific weight than the underlying calcareous mud, tended to sink into it, thus leading it to penetrate into the crack fractures. This is supported also by a few large marks on the plattenkalk calcareous layers, consisting of protruding margins around siliceous nodules with a diameter of many decimetres, sunk in the ancient mud of the sea bottom. As already remarked by D'Argenio (1963), these siliceous cracked chips, especially the smallest-sized ones, are found also displaced from their initial position and in local accumulations. Such an arrangement could be due to storms and represents another evidence of syngenetic silicification and of early diagenesis of these horizons. Finally chert is present most abundantly and with the most continuous horizons in what represented a distal area of the basin, far away from its shores and therefore more depressed. This too must be correlated to a higher specific weight, favouring the accumulation of siliceous gel in the deepest areas, as well as to a higher saturation of mud and water on the sea-bottom.

The marginal areas of Plattenkalk II show, also on the Civita plateau, the heteropic passage into detrital limestones similar to those of «Interval A» of the sequence. As already mentioned, this took place because the plattenkalk tapers and its layers interrupt with slightly higher slopes along the margins, against the embanked rocks. These marginal areas contain metric scale slumpings (Fig. 15), linked to higher slopes. These same marginal slumpings could have represented, in agreement with Freels (1975), an important cause of transport of sediment toward the centre of the basin, where the limited turbidity currents were generated. Evidences of currents, probably linked to the above-mentioned causes, are also present in certain layers of the distal area of the basin (represented by the typical «Le Cavere» outcrop). They consist of convoluted laminations present in some layers. On the basis of the already mentioned accumulations of small siliceous cracked chips which could be originated, in agreement with D'Argenio (1963), by the action of waves during storms or, less probably, to the aeolian action on surfaced sublayers, no certain marks of emersion and sediment drying up (mud cracks) can be observed in the plattenkalk layers, as stated by the aforesaid author.

Remarks on the fossilisation conditions of organisms and their environmental meaning

The layers of Pietraroia plattenkalks often contain abundant microfaunas, especially in the lower coarser-grained portions of the interbedded centimetric layers and horizons, deposited by small turbidites and suspension sediment decantation, brought by tide waves and storms. These organogenic components must therefore be considered as allochthonous, since they came from lagoonal areas with a less limited circulation, surrounding the basins of the plattenkalks. Therefore nanism of microfaunas cannot be linked to an environment characterised by high ecological stress in such basins, but rather to the relatively restricted lagoonal conditions existing in the surrounding areas, where the sediments originated from. Another non-negligible cause of a possible «apparent» nanism of the plattenkalk microfaunas can be the low kinetic energy of waves, which suspended the sediment from the above-mentioned areas surrounding the basins. The materials of the

Fig. 15 – Plattenkalk II at the left side of «Vallenova»: slumpings by the «flute-beak» termination of the Plattenkalk.

plattenkalk layers are actually always fine or very fine-grained, since the waves, once dampened, could suspend only the finest-grained fractions of sand and microfossiliferous mud, by selectively concentrating them in the plattenkalk basins, thus simulating the nanism of microfaunas. This seems to be confirmed both by the presence in plattenkalks of horizons with regular-sized microfaunas, and by the fact that a few rare regular-sized foraminifers are sometimes present in dwarf associations (Fig. 12). In the former case they represent sedimentary events with a higher kinetic energy; in the latter case, on the contrary, they are occasional coarser elements, transported with thinner sediments: these elements prove the existence of regular-sized microfaunas in the external areas adjoining the plattenkalk basins.

The abundance of sponge spicules that can be observed in several plattenkalk levels (Fig. 11) must not necessarily be linked to a deep sedimentation environment, such as the one considered by Catenacci & Manfredini (1963), since vast sponge colonies can develop also in shallow or very shallow water (the existence of sponge mounds in the areas surrounding the plattenkalk sedimentation basins in the Solnhofen and Kelheim areas is well documented (Meyer, 1981, Meyer & Schmidt-Kaler, 1984, Barthel et alii, 1990)). They could therefore reach the basins from neighbouring areas, together with finer sediments. The arrangement of spicules in the plattenkalk layers shows an isoorientation which can be due to the deposition modalities of the sediment. During the deposition of small turbidites co-

Fig. 16 – Upper surface of one limestone layer of Plattenkalk II, showing many valves of small bivalves, wide apart but still articulated at the umbone, with an upward concavity. These bivalves constitute part of the autochthonous benthos of the basin, which they entered as larvae, during periods of more frequent exchange with the open sea, subscquently dying there when the ecological conditions worsened, without reaching the adult stage. The fossilisation position is due to the remarkable overheating of the thin water layer and of the sediment where the bivalves lived. The upward concavity of the valves indicates the lack of sea-bottom currents. Sample: P.m.1. Locality: Civita di Pietraroia (BN): «Le Cavere». Layers of Plattenkalk II («Interval D» of the sequence). Age: late Lower Albian.

ming from the marginal areas of the basin, probably by low-speed currents, the light and very elongate spicules arranged their axes along the current's direction. In certain cases there is evidence of a change in the current's direction represented by the prevalence, in thin section, of subaxial or orthogonal sections of the axes of spicules, in consecutive horizons. We must not underestimate the role that spicules could have played as sources of silica for the formation of chert layers and nodules.

The presence in Plattenkalk II of a few stratum surfaces full of small bivalves with wide apart valves, still articulated at the umbones (Fig. 16) and with upward concavity, must be considered evidence of a strong overheating of a very thin water layer and of the sea-bottom sediment or, according to Bernier & Enay (1972), of possible temporary emersions. Personal observations carried out in a coastal lagoonal area of Campania («Variconi» swamp area, at the mouth of the Volturno river), proved that small digging bivalves (*Cerastoderma glaucum*) can take this dying position also near shores of stagnant environments not necessarily located above the sea level, in less-than-a-meter deep water. Similar observations are reported also by Ballesio & Patricot (in Bernier & Enay, 1972) on the marginal areas

of present shallow water environments in Camargue (France). The above-mentioned bivalves represent juvenile development stages, which might have entered the plattenkalk basin as larvae, during periods of more frequent exchange with the open sea, or the larve themselves might have been transported by the waves causing sedimentary supplies. But the development of these organisms, representing part of the autochthonous benthos, does not reach the most adult stage because of dystrophic conditions also due to a remarkable periodic water overheating.

As far as the ichthyofauna of Plattenkalk II is concerned, D'Erasmo (1915, 1946), comparing it to that of the Comen area outcrops, already remarked its coastal character. D'Argenio (1963) supported such observation, which led him, together with many others, to conclude that the Pietraroia outcrop, such as the Comen outcrops, formed in very shallow water, in a basin essentially isolated from the open sea, near a coast and with supply of fresh water. But this author noted the absence of continental flora and a lesser presence of reptilians in the Pietraroia outcrop. Today the palaeoenvironmental picture can be enriched by these elements: in fact the first meter of Plattenkalk II of «Le Cavere» contains laminated horizons, richer in bitumen than the regular layers, often containing very abundant plant remains and frustules, at times well preserved, part of which can be ascribed to Bennettitales (*Zamites*?) and Conifers (*Brachyphyllum*) (Figs. 17-18). Also the number of reptilian taxa is presently higher, and it includes, together with the Albanerpetontid amphibian *Celtedens megacephalus* (Costa) (McGowan & Evans, 1995), the lacertilian reptile *Costasaurus rusconi* (Costa), the sphenodont *Chometokadmon fitzingeri* (Costa), and *Derasmosaurus pietraroiae* Barbera, at least two specimens that can be ascribed to Mesosuchidae and a *Coelurosaurus* (Leonardi & Teruzzi, 1993).

The state of preservation of vertebrates is generally very good: their anatomical parts, even the most delicate, are actually almost always connected (Fig. 19). But in certain cases it is possible to observe the shift of easily disarticulated and small-sized parts from their original position (such as the articula constituting the radiuses of the fins of certain fishes). In any case the scattering of such parts around the carcass does not seem to follow a specific modality. In a few rare cases there are also incomplete carcasses (Fig. 20). Such evidence leads us to think that the basin lacked currents strong enough to scatter the carcass parts (except in particular moments, during turbiditic sedimentary events). When the scattering of small parts took place - not following any preferential direction from the carcass - this could be due mainly to bioturbation (Elder & Smith, 1988) (Fig. 21) caused by small necrophagous organisms, such as decapod crustaceans or turreted gastropods, of which only marks are found. The latter certainly constitute part of the autochthonous benthos of the plattenkalk basin (worm tracks are actually only occasional (see also D'Argenio, 1963). On the contrary the mutilation of certain carcasses (Fig. 20) can be due to floatage periods, when the decomposition processes favoured the detachment of bony parts, which are often found isolated on the layer surfaces. Also the dorsally arcuate position of certain ichthyolites (especially those of the genus *Clupavus*), due to the development of putrefaction gases in the abdominal cavity,
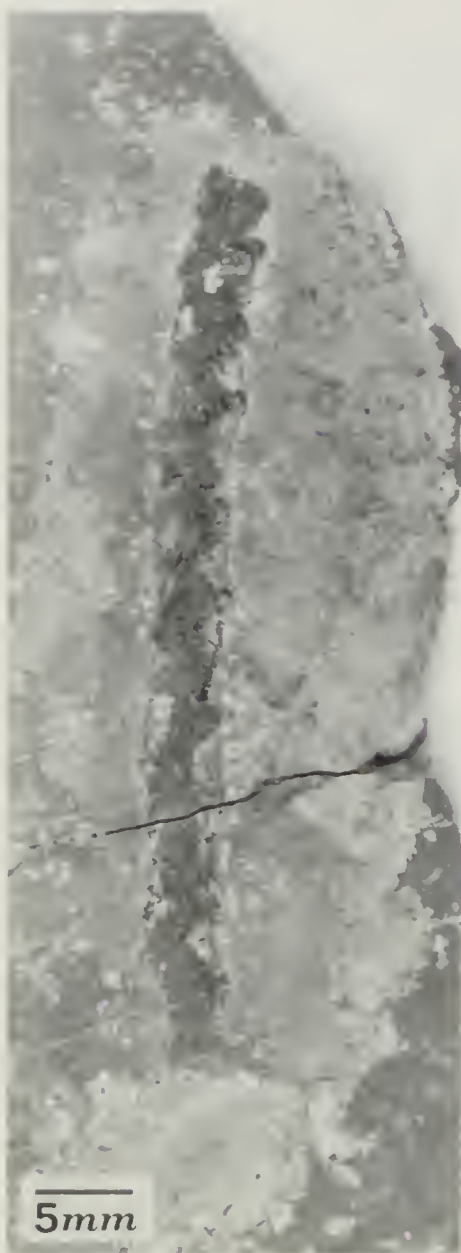
Fig. 17 – *Brachyphyllum*? sp.. Sample: P.v.3. Locality: Civita di Pietraroia (BN): «Le Cavere». Plant layers of Plattenkalk II («Interval D» of the sequence). Age: late Lower Albian.

Fig. 18 – *Zamites*? sp.. Lanceolate small leaves, with thickened margin and parallel longitudinal nervations. Sample: P.v.1. Locality: Civita di Pietraroia (BN): «Le Cavere». Plant layers of Plattenkalk II («Interval D» of the sequence). Age: late Lower Albian.

indicates a floatage stage. But these processes need suitable water temperatures (Smith & Elder, 1985, Elder, 1985, Elder & Smith, 1988) and a limited depth, since in high hydrostatic pressure conditions inside deep basins such putrefaction gases might not expand in the abdominal cavity of dead fish, causing a flotation. Except the aforesaid exceptions, the frequent state of perfect articulation of the parts of vertebrates may very possibly be linked to the development of bacterial and algal films on the sea-bottom and on carcasses, which carried out a stabilising action (Gall et alii, 1985), thus avoiding superficial erosion of the sea-bottom and disarticulation of organic
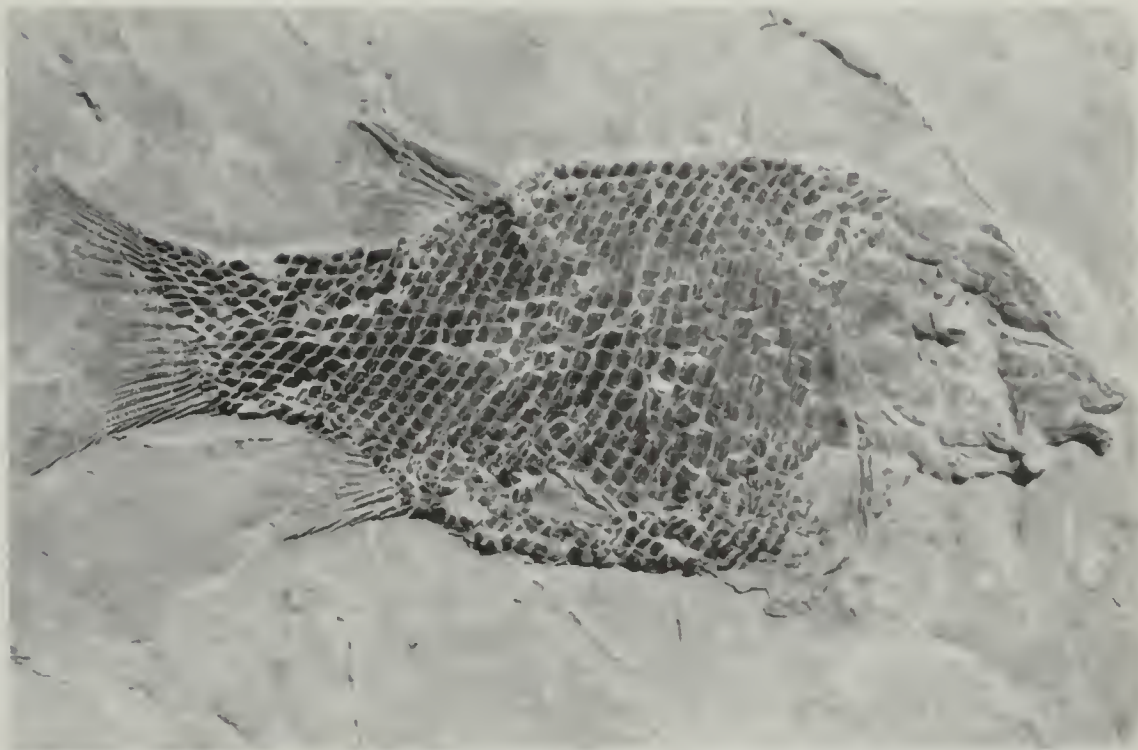
Fig. 19 – *Lepidotes* sp., a fish of the primitive group of «Ganoids». This species is very frequent in Plattenkalk II. It is possible to see the perfect state of preservation, and the most delicate parts (for example articula of the fin radiuses) are perfectly articulated. Specimen: M19252 (x0.6). Locality: Civita di Pietraroia (BN): «Le Cavere». Layers of Plattenkalk II. Age: late Lower Albian.

Fig. 20 – A pycnodont carcass (*Coelodus*), markedly mutilated and disarticulated. These preservation conditions are very probably linked to a flotation period of the carcass in a highly oxygenated environment, when a decomposition stage took place. Locality: «Le Cavere», Plattenkalk II.

Fig. 21 – A fossil fish (*Notagogus pentlandi* Agassiz) of Plattenkalk II, at «Le Cavere» site. Notice the slight disarticulation of most scales and of the articula constituting the caudal fin, slightly posteriorly shifted. These preservation conditions are probably linked to a bioturbation action, together with very weak sea-bottom currents.

remains by new sedimentary supplies. Such films could develop during more or less prolonged sedimentation pauses, represented by the thinly laminated and sometimes marly intervals, which are in fact the most fossiliferous.

As far as the causes of fauna mortality are concerned, the high quantity of coprolites on certain stratum surfaces (for example on the basic layer of «Le Cavere» quarry), together with the high number of fossil fishes, indicates non-sedimentary periods, due to the isolation of the basin from the sea, when the above-mentioned coprolites - produced by fishes trapped or living in the superficial water layers and in the most peripheral areas of the basin - concentrated on the sea-bottom (near which disaerobic conditions were quite frequent, due to water stratification). The results were overall dystrophic conditions of the basin (maybe with seasonal rhythms), which killed faunas by water overheating and subsequently by the development, in agreement with D'Argenio (1963), of bacterial and phytoplankton masses which, after decomposition, made the environment asphyctic by releasing sulphur hydrogen. Carcasses of terrestrial reptilians (*Coelurosaurus*) or fresh water reptilians (crocodiles) and amphibians (*Celtedens*), together with the remains of continental flora, could reach the basin after short floatage periods, either incidentally or transported by watercourses. The occasional influence of fresh water (see also D'Argenio, 1963) is also proved by the presence, in certain plattenkalk horizons, of flat and thin-valved ostracod concentrations. Such supplies could be the cause of the lack of pseudo-

morphous or marks of evaporitic minerals, which we would expect to find in a shallow coastal lagoonal environment, isolated from the sea and overheated.

In summary, the presence of continental faunas and floras, together with the presence of fish genera found also in fresh-water environments (for example: *Lepidotes* (see Gayet, 1982) and *Pleuropholis*, present also at Las Hoyas (Sanz et alii, 1988), which we believe formed in a fresh-water basin (Barale et alii, 1994, Fregenal-Martinez & Melendez, 1994)), is a further unmistakable evidence of the existence of lands above the sea-level in front of the plattenkalk basin. These continental areas, dwelling faunas including Coelurosaurids, had to be quite extended and persistent in time, and their ecological conditions were able to harbour complex trophic pyramids, at the top of which there were large-sized carnivorous reptilians.

Conclusions

The stratigraphical sequence of the upper part of the Civita di Pietraroia, at its NE side (Fig. 22), includes two plattenkalk horizons, the uppermost of which (Plattenkalk II) corresponds to the well known formation of «ichthyolitic limestones» of Pietraroia (D'Argenio, 1963, Catenacci & Manfredini, 1963). The age of the examined stretch (between the last layers of the formation immediately underlying the lowest plattenkalk (Plattenkalk I) and the Miocenic transgression), is included between the early Albian (detritic limestones with *Ovalveolina reicheli*) and the high part of the Lower Albian (last layers of Plattenkalk II, with *Paracoskinolina tunesiana*, *Cribellopsis cf. arnaudae*, *Sabaudia minuta*, «*Pseudonummoloculina*» sp. and evolved Cuneolines), and it wholly falls within the *Sabaudia minuta* biozone (De castro, 1991, Barattolo & De Castro, 1991). Such organism is present and well represented in the whole interval.

The substrate where the plattenkalks lie is characterised, in the contact point with the lowest one, by a quite articulated erosive surface. The age and facies of such substrate are perfectly comparable with those of the limestones immediately underlying the bauxite horizon, widely represented in the eastern Matese area, especially at Regia Piana and at the Pesco Rosito outcrop (D'Argenio, 1963, Catenacci et alii, 1963, Crescenti & Vighi, 1964, 1970, Bergomi et alii, 1975 and Carannate et alii, 1988). A probably analogous substrate of Albian age is present also in areas which are farther away from Pietraroia, such as Monte Maggiore, in the province of Caserta (Crescenti & Vighi, 1964, 1970 and Sartoni & Colalongo, 1964). The above-mentioned remarks, together with the fact that Pietraroia plattenkalks are here interpreted - basically in agreement with D'Argenio (1963) - as very thin sea facies, close to the limit of emersion, lead us to believe that plattenkalks and bauxites represent, in different positions within the platform, the same remarkable eustatic fall of the sea level. More particularly plattenkalks probably formed in a more external platform area than the completely emerged area, subject to karstic processes (Carannante et alii, 1988), where bauxites formed. In the early Albian a first substrate emersion stage took place, leading to the formation of the erosion surface. Subsequently, during low stand of the sea level, the conditions for plattenkalk deposition created within basins constituted by weakly depressed areas, protected by

detritic belts and shoals, into a tidal flat widened by the eustatic fall of the sea level. Carbonatic sedimentation in these basins was rapid and it originated especially from particularly strong tide waves and storms which, by sweeping adjoining areas and dampening before reaching the basins, poured the finest sediments into them. Such sediments deposited by turbiditic and decantation mechanisms. In the sometimes prolonged carbonatic non-sedimentation periods, dystrophic conditions created in the shallow plattenkalk basins (not causing a complete anoxia), killing faunas. A limited terrigenous supply could sometimes prevail (thinly laminated marls and clayey interstrata), linked to the presence of overlooking areas above the sea-level, where also land organisms of Plattenkalk II originated (plants, amphibians and reptilians).

The part of stratigraphical sequence examined at the Civita di Pietraroia actually proves the transition from quite «open» subtidal conditions (Interval A) to temporary continental conditions (erosive surface), followed by a low stand of the sea level, with a predominance of upper-subtidal-intertidal environments, when the two plattenkalks (Intervals B and D) sedimented in the weak depressions of the platform, separated by a more coarsely detritic facies, also thinly stratified, but which deposited in a relatively more open subtidal environment (Interval C).

After the palaeoecological and biostratigraphic analysis of the plattenkalks of the Civita of Pietraroia, the carcinological sample of this outcrop has been studied in every detail.

Materials

The examined sample, housed in the palaeontological collections of the Museo di Paleontologia di Napoli, consists of 29 specimens of macruran and anomuran decapod crustaceans, found during the 1982 excavation and during the last 1996 excavation. The preliminary analysis of this sample has pointed out a not particularly good state of preservation, allowing to select only 17 specimens of sure systematic ascription. Among these specimens, one has been ascribed to the new genus *Micropenaeus* with the species *M. tenuirostris* n.sp. (infraorder Penaeidea de Haan, 1849, family Penaeidae Rafinesque, 1815) and fourteen have been ascribed to the new genus *Parvocaris* with the species *P. samnitica* n.sp. (infraorder Caridea Dana, 1852, indeterminate family). The infraorder Astacidea Latreille, 1803 is represented by two specimens not ascribed to any fossil genera and species known to date. Finally, the specimen marked by catalogue number M20885 is a big piece of stratum on which 12 specimens are preserved, all belonging to the new genus *Huxleycaris* with the species *H. beneventana* n.sp. (infraorder Anomura Milne-Edwards, 1832, family Axiidae Huxley, 1879).

Besides the carcinological sample, a well preserved specimen of isopod (M20903) not described in this paper was found among the invertebrates.

The study of macruran decapod crustaceans of the Lower Cretaceous of Pietraroia (Benevento, S Italy) is part of a research programme on lithographic limestones of Campania that the Palaeontology Department of the Università di Napoli has been carrying out for many years; moreover, this study is part of a research programme on Mesozoic macruran decapod cru-
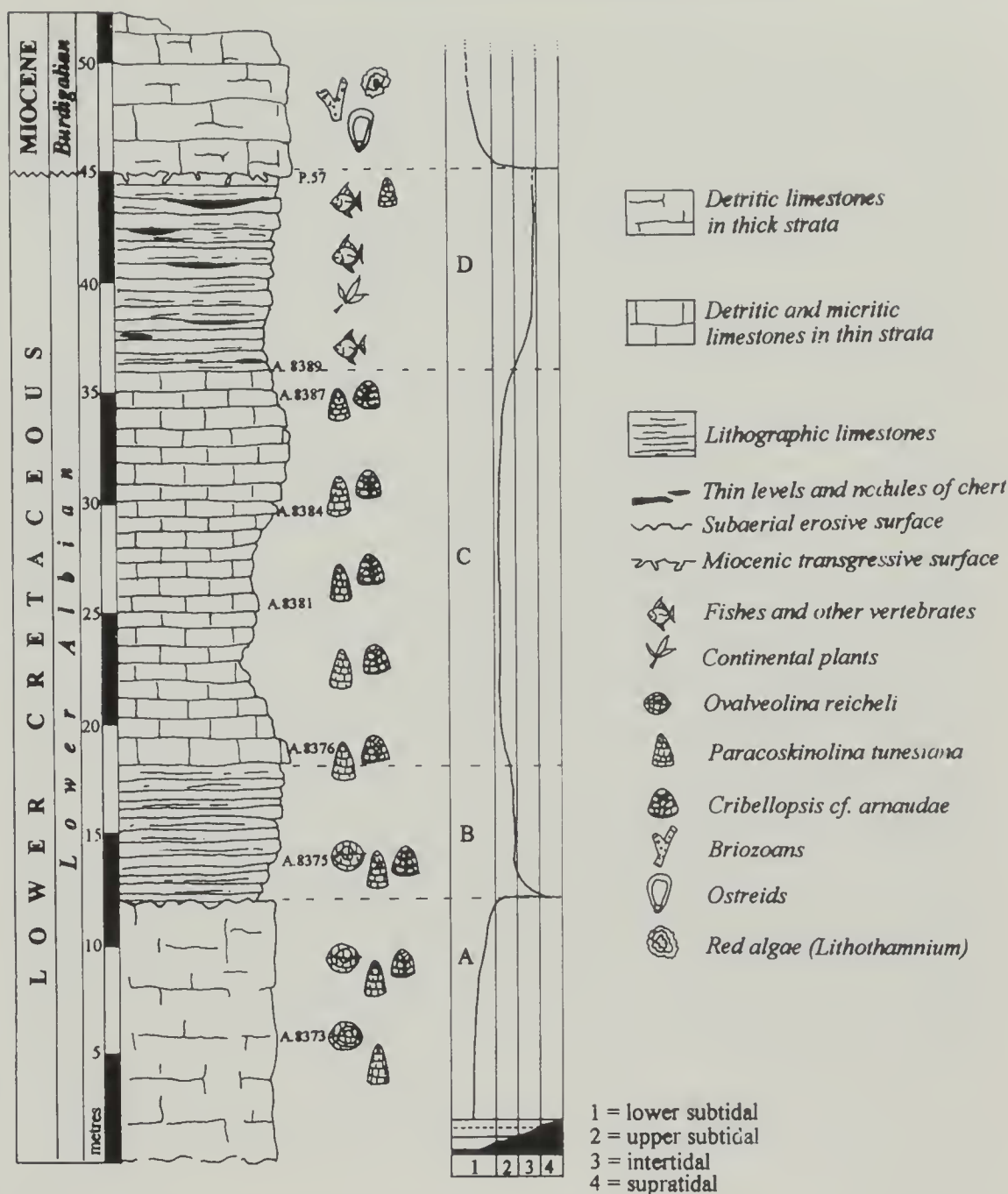
Fig. 22 – Stratigraphical sequence of the NE side of the Civita di Pietraroia and relevant changes in the deposition environment.

staceans that the Invertebrate Palaeontology Department of the Museo di Storia Naturale di Milano has been carrying out for many years on materials from its own and other Museums' collections. Up to now this programme brought to the description of important Italian and foreign Mesozoic faunistic assemblages, such as the Triassic association of the Ambilobè region (NW Madagascar) (Garassino & Teruzzi, 1995), of Cene (Seriana Valley, Bergamo - N Italy) (Pinna, 1974), of Prati di Rest (Valvestino, Brescia - N Italy) (Pinna, 1976), of Ponte Giurino (Imagna Valley, Bergamo - N Italy)

(Garassino & Teruzzi, 1993) and of Carnia (Udine, NE Italy) (Garassino, Teruzzi & Dalla Vecchia, 1996); the Lower Jurassic of Osteno (Lugano Lake, Como - N Italy) (Pinna, 1968, 1969, Garassino & Teruzzi, 1990, Teruzzi, 1990 and Garassino, 1996) and the Cretaceous assemblages of Trebiciano (Trieste, NE Italy) (Garassino & Ferrari, 1992), of the Lebanese outcrops (Garassino, 1994), of Las Hoyas (Cuenca, Spain) (Garassino, 1997), of Petina (Alburni Mounts, Salerno - S Italy) (Bravi & Garassino, 1997) and of Torrente Cornappo Valley (Udine, NE Italy) (Garassino, 1997).

Previous studies on macruran decapod crustaceans of Pietraroia

Six specimens of macruran decapod crustaceans found during the first excavations led on lithographic limestones of the Civita of Pietraroia and previously housed in the Museo Geologico di Napoli, were studied by Oronzio Gabriele Costa in three following steps (Costa, 1864, 1865a,b). The author ascribed these specimens to three new species: *Astyages effossus* (Costa, 1864, part III, vol. VIII, Tab. XIV, figs. 1-4; Costa, 1865a, Tab. III, figs. 11-12), *Trichocerus monticellianus* (Costa, 1865b, Tab. III, fig. 10) and *Branchipus gigas* (Costa, 1865b, Tab. III, fig. 2).

These specimens were subsequently reviewed by D'Erasmo (1915), who ascribed them with uncertainty to the same genus *Pseudastacus* Oppel, 1861. As the author pointed out the examined specimens «...Sono disgraziatamente quasi tutti in pessimo stato di conservazione, sicchè non permettono che una breve e incompleta descrizione...». It is for this reason that the author ascribed these specimens only to the genus, omitting the specific ascription.

The impossibility to study the original specimens, now lost, at the Museo Paleontologico di Napoli has not allowed to establish possible morphological affinities with the examined specimens. However, after carefully reading D'Erasmo's description (D'Erasmo, 1915, Tab. V, fig. 4) we do not recognise any affinities with the three genera described by Costa.

Acronym. M: Museo di Paleontologia di Napoli

Systematics

Infraorder Penaeidea de Haan, 1849
Family Penaeidae Rafinesque, 1815

Genus *Micropenaeus* nov.

Diagnosis: subrectangular carapace; short rostrum with at least four suprarostral teeth; hepatic spine; somite VI strongly elongate.

Derivatio nominis: from Greek micro=small, for the microscopic size of this penaeid.

Type species: *Micropenaeus tenuirostris* n.sp.

Description: as for the type species.

Micropenaeus tenuirostris n.sp.
Fig. 23

Derivatio nominis: from Latin tenuis=short, for the short size of the rostrum.

Holotype: M21833.

Type locality: Pietraroia (Benevento, S Italy).

Geological age: Lower Albian (Lower Cretaceous).

Diagnosis: as for the genus.

Materials: only one specimen in good state of preservation and in lateral view.

Description. It is a small penaeid with thin and completely smooth exoskeleton, 1.2 cm in length.

Carapace. In lateral view, the carapace has a subrectangular shape and gets slightly narrow toward the anterior margin for the slight curvature of the ventral margin. The dorsal margin is straight, while the posterior margin, strengthened by a thin marginal carina, has a slight concavity in the lower third. The ventral margin is straight. The dorsal margin extends into a short rostrum with pointed distal extremity and with at least four identical and forward protruded suprarostral teeth. The subrostral teeth are not present. The ocular incision is narrow and shallow and the antennal and pterygostomial angles are not very marked. A strong hepatic spine is present on the surface of the carapace.

Abdomen. Somites I-V have a subrectangular shape and an even length. The posterior margin of somites I-V is slightly sinuous. Somite VI is strongly elongate, reaching twice the length of the other somites. The telson has a triangular shape and pointed distal extremity. The uropods are badly preserved. The exopodite, lacking any ornamentation, is without diaeresis.

Cephalic appendages. Badly preserved. The eye is supported by a long eye-stalk. The antennulae consist of three articula: the 1st and the 2nd are thin and elongate, while the 3rd is short and stocky. The scaphocerite has a laminar shape.

Thoracic appendages. Only fragments of the pereiopods are preserved.

Abdominal appendages. The pleopods are not preserved.

Observations

At present, the only known penaeid of the Cretaceous of Italy is *Penaeus vernassensis* Garassino & Teruzzi, 1995, found near the village of Vernasso (Udine, NE Italy) and recently described (Garassino & Teruzzi, 1995). Garassino & Ferrari (1992) reported in the Senonian (Upper Cretaceous) of Trebiciano (Trieste, NE Italy) the presence of a new probable form of penaeid, without describing it because of the bad state of preservation of the examined sample.

The lack in the examined specimen of some typical characters of the genus *Penaeus* Fabricius, 1798, such as the rostrum with supra- and subrostral teeth, the cervical, orbito-antennal and hepatic grooves and the antennal spine, do not allow to ascribe it to this genus, justifying the institution of the new genus *Micropenaeus*.

Infraorder Caridea Dana, 1852
Family indet.

Genus *Parvocaris* nov.

Diagnosis: subrectangular carapace; long rostrum with at least nine su-
prarostral teeth; somite II with subround pleura overlapping that of somite
I and III; pereiopods I-II with merus and propodus strongly elongate; exo-
podite with diaeresis.

Derivatio nominis: from Latin parvus=small, for the small size of the
body.

Type species: *Parvocaris samnitica* n.sp.

Description: as for the type species.

Parvocaris samnitica n.sp.
Fig. 24, 25

Derivatio nominis: from Latin samniticus=from Sannio, pre-roman na-
me of the area where the Pietraroia outcrop is located.

Holotype: M20545.

Paratypes: St5/29, M20571, M20525.

Type locality: Pietraroia (Benevento, S Italy).

Geological age: Lower Albian (Lower Cretaceous).

Diagnosis: as for the genus.

Materials: 14 complete specimens, in good state of preservation. Most
specimens are in lateral view, one in dorsal view and one in ventral view.

M: 19309, 19334, 19344, 19373, 19389, 20525, 20545, 20571, 20723, 20772,
20773, St5/29, St7/7, St7/8.

Description. It is a small-sized caridean with thin and completely
smooth exoskeleton, 1 to 1.5 cm in length.

Carapace. In lateral view, the carapace has a subrectangular shape and
gets slightly narrow toward the anterior margin for the slight curvature of
the ventral margin. The dorsal margin is straight, while the posterior mar-
gin, strengthened by a thin marginal carina, is sinuous with a slight conca-
vity in the lower third. The ventral margin is curvilinear. The dorsal margin
extends into a long and straight rostrum with pointed distal extremity, bea-
ring many identical and forwards protruded suprarostral teeth (there are at
least nine teeth in the specimen M20525). The subrostral teeth are lacking.
The ocular incision is shallow and the antennal and pterygostomial angles
are not very marked. No traces of grooves, carinae and spines can be obser-
ved on the surface of the carapace.

Abdomen. The somites have subrectangular shape and an even length.
Somite II has a subround pleura partially overlapping that of somite 1 and
III. The posterior margin of somite III is slightly sinuous, while it is
backwards protruded in somite IV-V. Somite VI has an almost square sha-
pe. The tail fan is badly preserved in all specimens. The telson with triangu-
lar shape and with pointed distal extremity can be observed only in a few
specimens. The uropods, lacking any ornamentation, are not longer than the
telson. The outside lateral margin of the exopodite is strengthened by a thin

carina converging to the distal extremity of the margin itself, thus creating a small spine by the upper margin of the rounded diaeresis.

Cephalic appendages. Badly preserved in all specimens. Only in a few specimens there are fragments of antennular and antennal flagella and the scaphocerite with a laminar shape and pointed distal extremity.

Thoracic appendages. They are visible in almost all specimens. The 3rd maxilliped is not preserved. Pereiopods I-II are chelate and increasing in length; the merus and the propodus are strongly elongate, while the carpus is short and stocky. The dactylus and the index of the chela are slightly curved and of even in length. Pereiopods III-V are incomplete and the articles are generally thinner than those of pereiopods I-II.

Abdominal appendages. The pleopods are not preserved.

Observations

Carideans are very rare in the fossil record and their morphological features are not well known because of their poor state of preservation.

The most ancient genera known to date, *Acanthinopus* Pinna, 1974 and *Leiothorax* Pinna, 1974, were discovered in the Calcare di Zorzino (Norian, Upper Triassic) of Bergamo Prealps (Cene, Seriana Valley - Bergamo, N Italy) (Pinna, 1974). Another form, *Pinnacaris* Garassino & Teruzzi, 1993, was discovered in the Argilliti di Riva di Solto (Sevatian, Upper Norian-Lower Rhaetian, Upper Triassic, according to the authors) of Ponte Giurino (Imagna Valley - Bergamo, N Italy) (Garassino & Teruzzi, 1993).

Glaessner (1969) ascribed only the genus *Udorella* Oppel, 1862 (family Udorellidae Van Straelen, 1924) to Jurassic. The same author ascribed also three *incertae sedis* Jurassic genera to carideans: *Blaculla* Münster, 1839, *Hefriga* Münster, 1839 and *Udora* Münster, 1839.

We presently know four species of Cretaceous carideans.

Martins-Neto & Mezzalira (1991a) found a few specimens of carideans in the Crato Member of Santana Formation (Lower Cretaceous) of Brazil. The perfect state of preservation of these specimens allowed the authors to describe the new genus *Beurlenia* (family Palaemonidae Rafinesque, 1815) with the species *B. araripensis*.

Roger (1946) described the new species *Notostomus cretaceus* on a sample of five specimens found in the Santonian (Upper Cretaceous) of Sahel Alma (Lebanon). This species was the subject of a recent review by Garassino (1994), who ascribed the species by Roger to the new genus *Odontochelion* (family Oplophoridae Dana, 1852).

Rabadà (1993) described the new genus *Delclosia* with the species *D. martinelli* on a sample of 60 specimens of the Lower Barremian (Lower Cretaceous) of Las Hoyas (Cuenca, Spain). This genus was the subject of a recent review by Garassino (Garassino, 1997).

Bravi and Garassino (1997) recently described the new genus *Alburnia* with the species *A. petinensis* (family Palaemonidae Rafinesque, 1815) on a sample of 3 specimens of the Lower Cretaceous (Albian) of Petina (Alburni Mounts, Salerno - S Italy).

Garassino & Ferrari (1992) reported the presence of only one specimen of caridean in the Senonian (Upper Cretaceous) of Trebiciano (Trieste, NE Italy), without ascribing it to a known family, genus and species. Garas-

sino & Teruzzi (1995) recently reported the probable presence of a new caridean form in the Upper Hauterivian-Lower Barremian (Lower Cretaceous) of Vernasso (Udine, NE Italy) (Garassino & Teruzzi, 1995).

Only four genera of carideans are presently known in the Tertiary deposits.

Four species belong to the genus *Bechleja* Hoŭsa, 1956, a typical form of freshwater deposits: *B. rostrata* Feldmann et alii, 1981 from the Eocene of the Green River Formation (Wyoming, USA); *B. inopinata* Hoŭsa, 1956 from the Oligocene of Czechoslovakia; *B. bahiaensis* (Beurlen, 1950) and *B. robusta* Martins-Neto & Mezzalira, 1991 from the Oligocene of Brazil (Beurlen, 1950, Hoŭsa, 1956, Feldmann et alii, 1981, Martins-Neto & Mezzalira, 1991b).

In the Miocene deposits of N Caucasus (Russia) the three genera *Palaemon* Weber, 1795, *Pasiphea* Savigny, 1816 and *Bannikovia* Garassino & Teruzzi, 1996 were described, with the species *P. mortuus* Smirnov, 1929, *P. mortua* Smirnov, 1929 and *B. maikopensis* Garassino & Teruzzi, 1996 (Smirnov, 1929, Garassino & Teruzzi, 1996).

Patricelli et alii (in press) recently ascribed a sample of over 40 complete and fragmentary specimens to the new species *Palaemon vesolensis* (family Palaemonidae Rafinesque, 1815), found in the Upper Cretaceous deposits of Vesole Mount (Salerno, S Italy).

On the grounds of what described, the species *Parvocaris samnitica* n.sp. and *Alburnia petinensis* n.sp. are therefore the only carideans of Cretaceous of Italy known to date. Two characters of *P. samnitica* n.sp., such as the rostrum with at least nine suprarostral teeth and pereiopods I-II with merus and propodus of the chela elongate, clearly distinguish the species of Pietraroia from that of Alburni Mounts.

Finally, some characters of the genus *Parvocaris* nov., such as the rostrum with many suprarostral teeth and the strong extension of merus and propodus of the chela are insufficient for the sure systematic ascription to any fossil or living known family, since these characters are common to many families of carideans.

Infraorder Astacidea Latreille, 1803
family, genus et species indet.

Materials: 2 complete specimens in bad state of preservation, 1.5 cm in length.
M: 20547, 20724.

The bad state of preservation of the examined specimens does not allow to ascribe them to any known fossil genus or species. However, the general morphology of the body, the rostrum and pereiopod I with short and stocky chelae are sufficient to ascribe the specimens to the infraorder Astacidea Latreille, 1803.

The examined specimens could have some analogies with the specimens ascribed by D'Erasmo (1915) to the genus *Pseudastacus* Oppel, 1861. However, the impossibility to study the original sample and the bad state of preservation of the examined specimens do not allow any type of comparison.

Infraorder Anomura H. Milne-Edwards, 1832
Superfamily Axioidea Huxley, 1879
Family Axiidae Huxley, 1879

Genus *Huxleycaris* nov.

Diagnosis: subrectangular carapace; short and strong rostrum; gastric region with three strong and toothed carinae; deep cervical groove located quite forward in the anterior part of the carapace; linea thalassinica not present; pereiopods I-II chelate; pereiopods III-V with terminal dactylus.

Derivatio nominis: in honour of Prof. Thomas Huxley who established the family Axiidae, to which the new genus belongs.

Type species: *Huxleycaris beneventana* n.sp.

Description: as for the type species.

Huxleycaris beneventana n.sp.
Figs. 26, 27, 28, 29

Derivation nominis: from Latin beneventanus=of Benevento, the province where Pietraroia outcrop is located.

Holotype: M20885 (No. 1).

Paratypes: M20885 (No. 2,4,9).

Type locality: Pietraroia (Benevento, S Italy).

Geological age: Lower Albian (Lower Cretaceous).

Diagnosis: as for the genus.

Materials: 12 specimens in good state of preservation, in lateral and in ventral view. As previously pointed out, catalogue number M20885 indicates a certain number of specimens, preserved on the same layer surface. All specimens were studied, but for the detailed description of the species six specimens marked by the following Arabic numerals were considered: 1, 2, 3, 4, 5, 9.

Description. It is a medium-sized thalassinid with thin and completely smooth exoskeleton, 1.5 to 3 cm in length.

Carapace. In lateral view, the carapace has a subrectangular shape and gets slightly narrow toward the anterior margin for the slight curvature of the ventral margin. The dorsal margin is straight and it bends markedly near the cervical groove. The posterior margin, strengthened by a thin marginal carina, is sinuous, with a slight concavity in the lower third. The dorsal margin extends into a short and strong rostrum with rounded distal extremity. Three strong and toothed carinae running parallel are present in the gastric region. The ocular incision is wide and deep and the antennal and pterygostomial angles are not preserved. On the surface of the carapace a deep cervical groove is present, originating in the anterior third of the dorsal margin and running towards the anterior margin following a curvilinear path. A narrow gastric region and a wide branchial region are created by the quite forward position of the cervical groove. The linea thalassinica is not present. The carapace is shorter than the abdomen, as in all thalassinid crustaceans.

Abdomen. Somites I-V have a subrectangular shape and uniform length. The posterior margin of all somites is almost straight. Somite VI has

a subsquare shape. The telson has a subrectangular shape and the uropods are badly preserved in all specimens.

Cephalic appendages. Badly preserved in all specimens. Only the eye supported by a short eye-stalk and fragments of antennular and antennae flagella are preserved.

Thoracic appendages. The 3rd maxilliped is not preserved. The chelate pereiopod I has a short and stocky carpus and a strong and elongate propodus. As can be observed in specimen No. 3, the dactylus is longer than the index and they have a slightly curved distal extremity. Pereiopod II has a little chela with internal dactylus, while pereiopods III-V have a terminal dactylus. The lower margin of the propodus of pereiopods III-V shows the insertion of a row of spines. Pereiopod I is stronger than the other pereiopods, as can be observed in all thalassinid crustaceans.

Abdominal appendages. The pleopods are preserved only in a few specimens. The pleopods consist of a subrectangular sympodite to which two elongate multiarticulate flagella are articulated.

Observations

The examined specimens have some typical characters of thalassinid crustaceans, such as the carapace shorter than the abdomen, the quite forward position of the cervical groove and pereiopod I stronger than other pereiopods.

The classification of thalassinid crustaceans has been extremely controversial for a long time.

However, according to the new classifications proposed first by Saint Laurent (1979) and then by Poore (1994), the infraorder Thalassinidea is presently subdivided into three superfamily: Thalassinoidea Dana, 1852, Callianassoidea Dana, 1852 and Axioidea Huxley, 1879, each one with one, six and four families respectively.

The lack of the typical linea thalassinica in the examined specimens definitely rules out their belonging to the superfamilies Thalassinoidea Dana, 1852 and Callianassoidea Dana, 1852.

Among the families belonging to the superfamily Axioidea Huxley, 1879, the family Axiidae Huxley, 1879 shares the most affinities with the specimens of Pietraroia. The main characters of this family were pointed out by Poore (1994), such as the carapace shorter than the abdomen, the presence of a well developed rostrum, the presence of a deep cervical groove, the lack of linea thalassinica, pereiopods I-II chelate and pereiopods III-V with terminal dactylus. These characters are found also in the new fossil genus *Huxleycaris*, which has therefore been ascribed to this family.

At present, five fossil genera ascribed to the family Axiidae Huxley, 1879 (Glaessner, 1969) are known: *Axius* Leach, 1815 of the Oligocene of Panama, *Etallonia* Oppel, 1861 and *Magila* Münster, 1839 of the Upper Jurassic of Germany, *Protaxius* Beurlen, 1930 of the Upper Jurassic of England and *Schlueteria* Fritsch, 1887 of the Upper Cretaceous of Czechoslovakia.

On the basis of the description and reconstruction of the genus *Schlueteria* Fritsch, 1887 reported by Glaessner (1969, pag. R477, Fig. 283), it is possible to distinguish and justify with certainty the institution of the new

genus *Huxleycaris* by three characters, such as the different structure of the well developed rostrum with rounded distal extremity, the structure of the chela of pereiopodi, which is shorter and toothless in the internal margins of dactylus and index and the different structure of the chela of pereiopod II, which is thinner and more elongate.

The general structure of the body, with a strong carapace and above all with an abdomen looking like the typical morphology of macruran decapods, and especially the structure of the chela of pereiopod I, which clearly differs from that of thalassinids «*sensu stricto*», since it is almost always chelate and never subchelate, lead us to suppose that the specimens of the genus *Huxleycaris* nov. did not build complex underground galleries in the muddy or sandy sediment. This typical behaviour can instead be compared to a more elongate structure of the body, with the loss of the rostrum, with pereiopods specialised for a fossorian activity and in particularly with an extreme flexibility between the carapace and the first somite observed in the typical representatives of the superfamily Callianassoidea Dana, 1852.

We can therefore suppose that the representatives of the genus *Huxleycaris* nov. probably lived in short galleries, dug in the muddy or sandy sediment, or lived in the ravines of the rocks.

Acknowledgements

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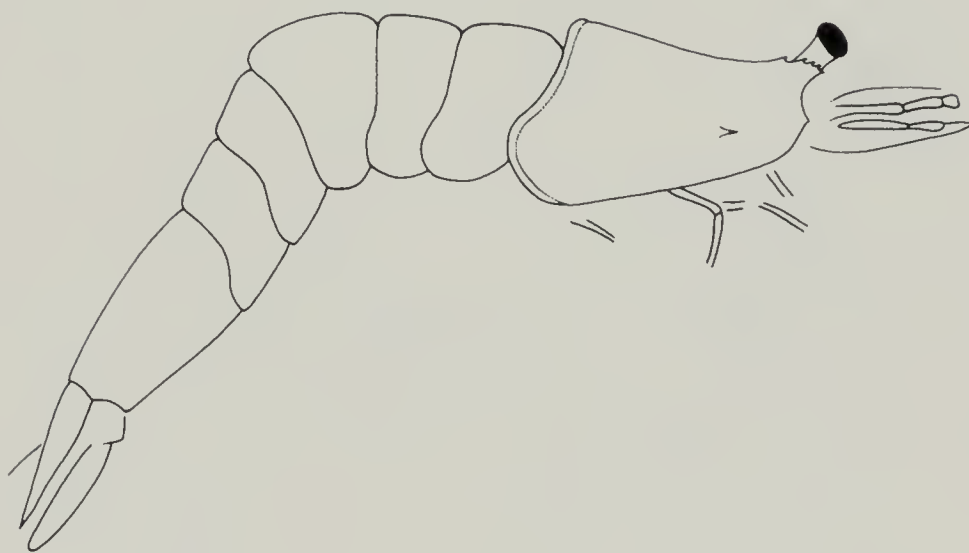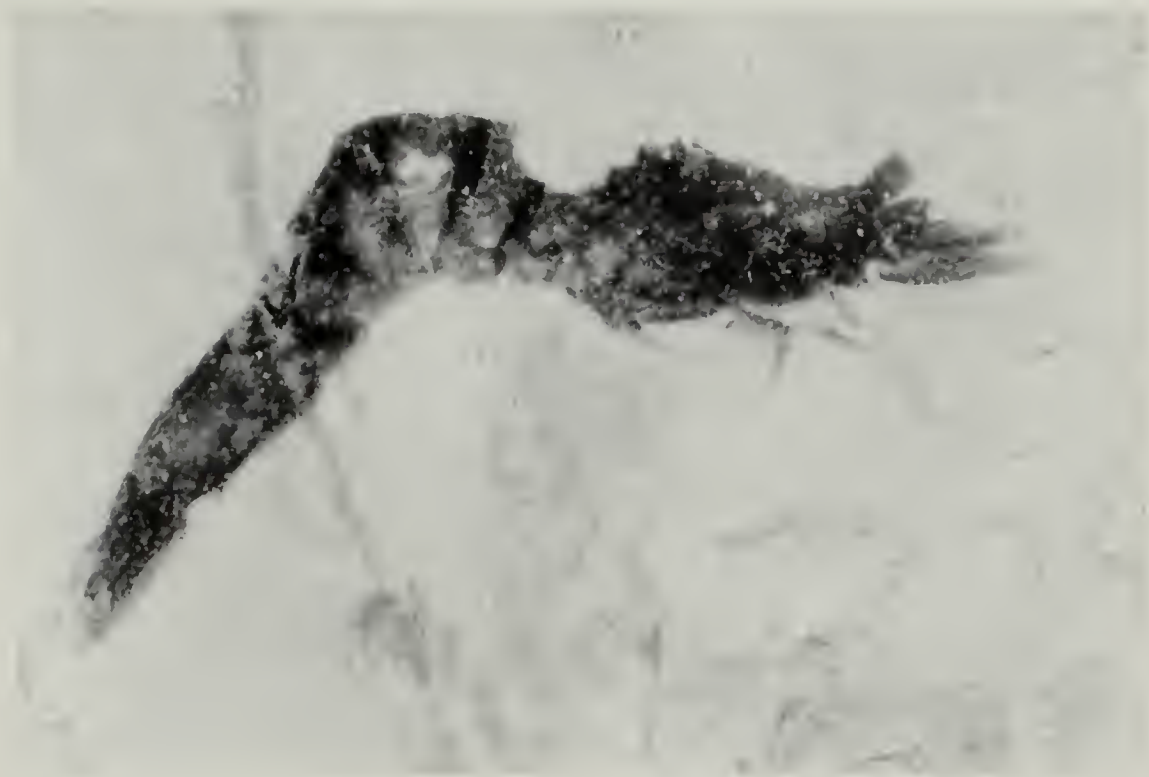
Fig. 23 – *Micropenaeus tenuirostris* n.ge.n.sp., holotype, n. cat. M21833, photo and reconstruction (x 8).
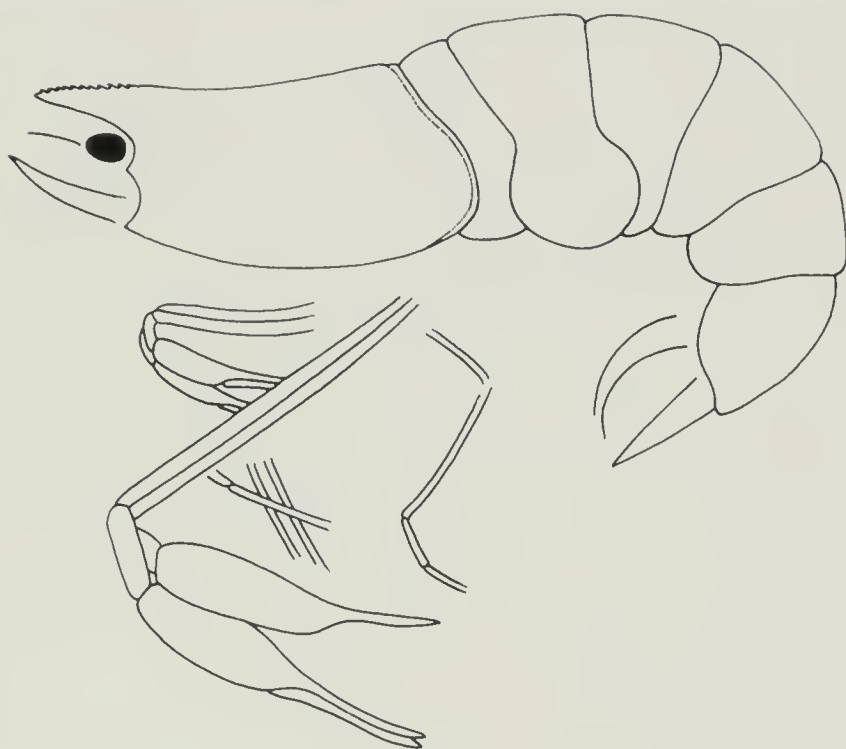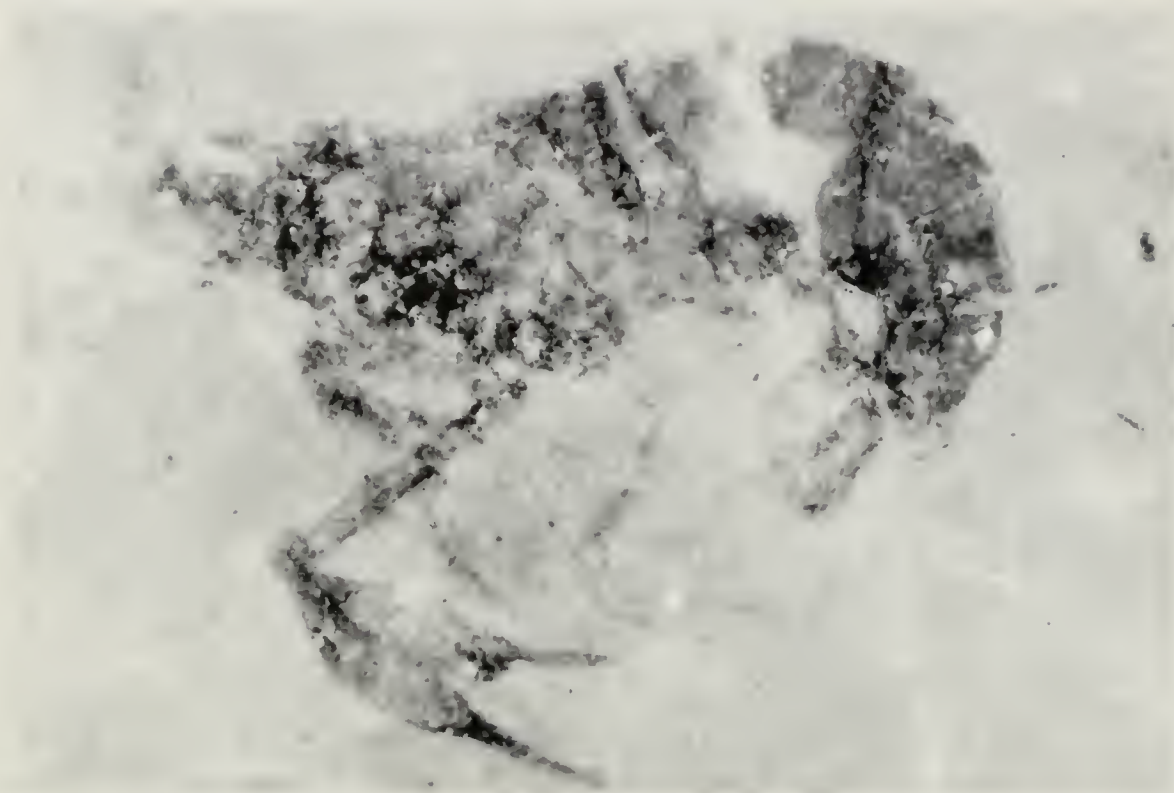
Fig. 24 – *Parvocaris samnitica* n.gen.n.sp., holotype, n. cat. M20545, photo and reconstruction (x 11).
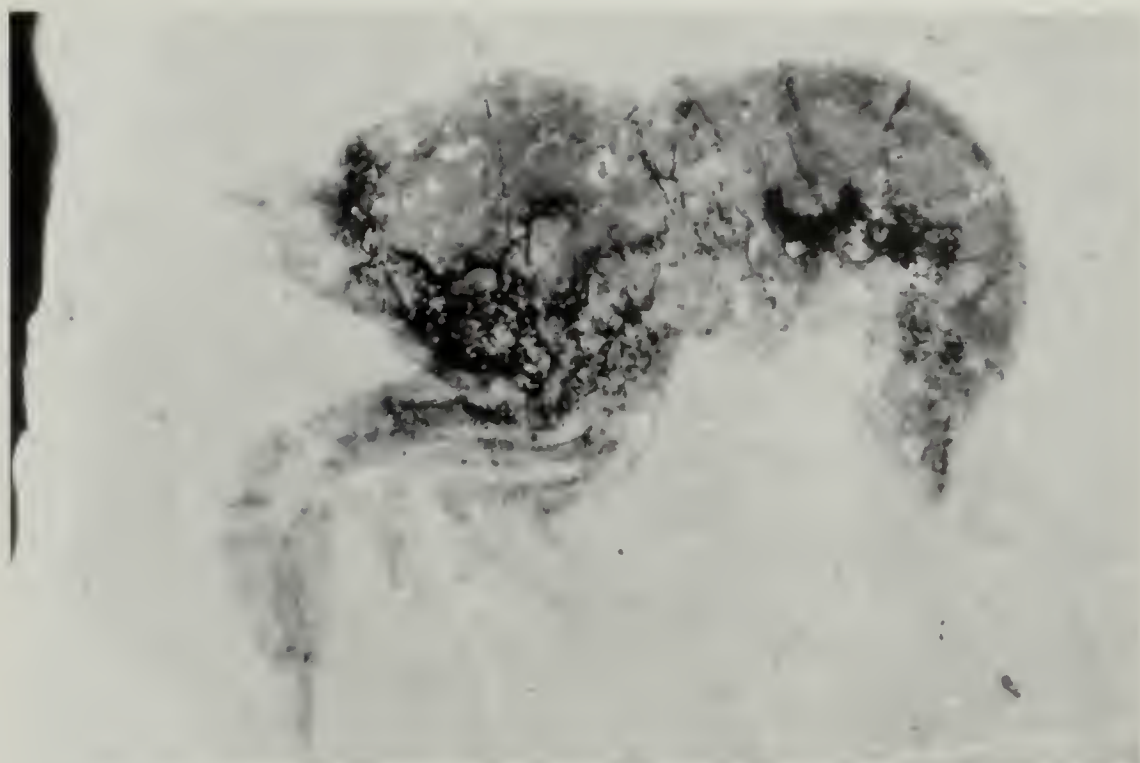
Fig. 25 – *Parvocaris samnitica* n.gen.n.sp., n. cat. M20571, photo and reconstruction (x 10).

Fig. 26 – *Huxleycaris beneventana* n.gen.n.sp., holotype, n. cat. M20085 (No. 1), photo and re-construction (x 2.8).
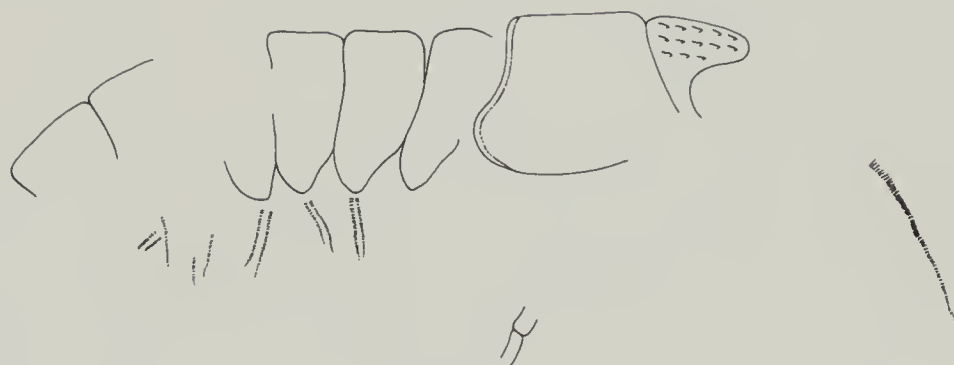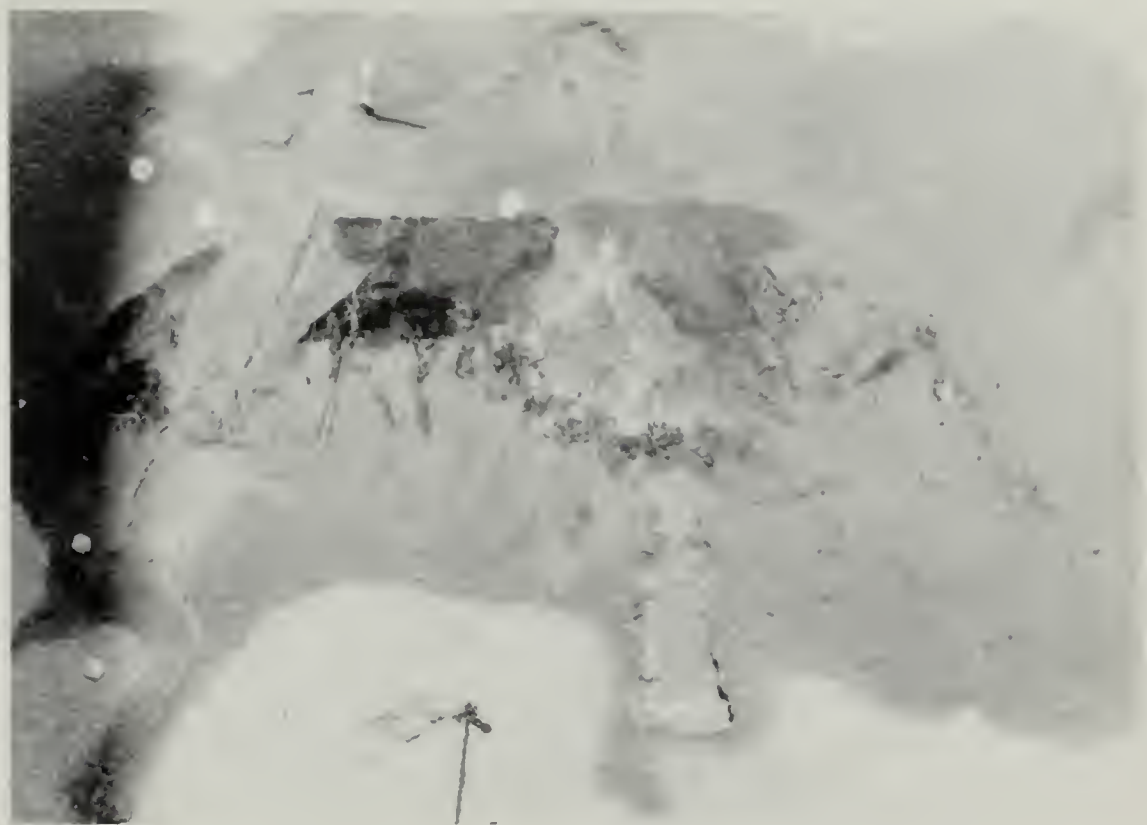
Fig. 27 – *Huleycaris beneventana* n.gen.n.sp., n. cat. M20085 (No. 9), photo and reconstruction (x 2.2).
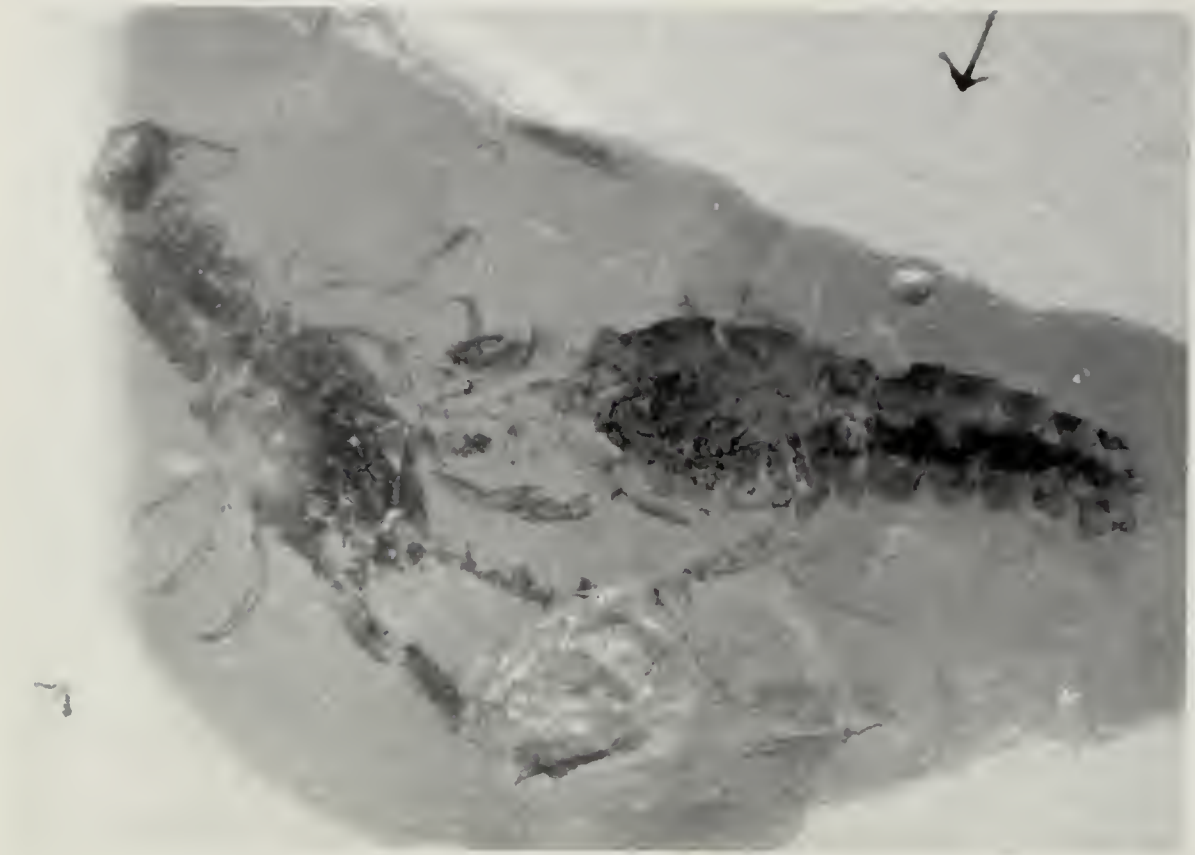
Fig. 28 – *Huxleycaris beneventana* n.gen.n.sp., n. cat. M20085 (No. 4), photo and reconstruction (x 3)
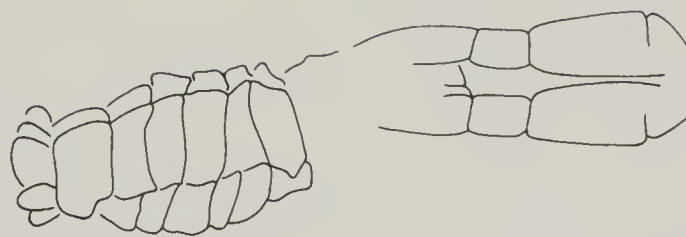
Fig. 29 – *Huxleycaris beneventana* n.ge.n.sp., n. cat. M20085 (No. 2), photo and reconstruction (x 3).